

DOCUMENT RESUME

ED 294 746

SE 049 141

TITLE Science & Engineering Indicators--1987.
INSTITUTION National Science Foundation, Washington, D.C.
 National Science Board.
REPORT NO NSB-87-1
PUB DATE 87
NOTE 382p.; Charts and graphs are printed on purple-colored paper and may not reproduce well. For a related document, see SE 049 143.
AVAILABLE FROM Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (\$17.00, stock no. 038-000-00578-2).
PUB TYPE Reports - Descriptive (141)
EDRS PRICE MF01/PC16 Plus Postage.
DESCRIPTORS *College Science; *Educational Research; *Engineering Education; Graduate Study; Higher Education; *Research and Development; Science Education; Scientific Research; *Secondary School Science; *Statistical Data; Teacher Characteristics; Technology; Undergraduate Study
IDENTIFIERS *National Science Board; National Science Foundation

ABSTRACT

This volume was written to reflect an increased awareness of the complementary roles played by science and engineering research and engineering in creating both new knowledge and new technological products and processes. It was designed to provide a broad base of quantitative information about the structure and function of science and technology in the United States in order to inform national policymakers who must allocate resources to these activities. Many feel that it is essential to this process that policymakers understand indicators well enough to properly support basic research, applied research and development, innovation and education. Profiles include: (1) "Precollege Science and Mathematics Education"; (2) "Higher Education for Scientists and Engineers"; (3) "Science and Engineering Workforce"; (4) "Resources for R&D and Basic Research"; (5) "Academic R&D and Basic Research: Patterns of Performance"; (6) "Industrial Research and Technological Innovation"; (7) "International Markets for U.S. Technology"; and (8) "Public Attitudes toward Science and Technology." Appendices include statistical tables, contributors and reviewers. (CW)

 * Reproductions supplied by EDRS are the best that can be made *
 * from the original document. *

ED294746

SCIENCE & ENGINEERING INDICATORS - 1987

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

☒ This document has been reproduced as
received from the person or organization
originating it.

☐ Minor changes have been made to improve
reproduction quality.

• Points of view or opinions stated in this docu-
ment do not necessarily represent official
OERI position or policy.



NATIONAL SCIENCE BOARD

SE 049 M1

NATIONAL SCIENCE BOARD

ROLAND W. SCHMITT (Chairman, National Science Board), Senior Vice President, Science and Technology, General Electric Company

CHARLES E. HESS (Vice Chairman, National Science Board), Dean, College of Agricultural and Environmental Sciences, University of California at Davis

PERRY L. ADKISSON, Chancellor, The Texas A&M University System

ANNELISE G. ANDERSON, Senior Research Fellow, The Hoover Institution, Stanford University

WARREN J. BAKER, President, California Polytechnic State University, San Luis Obispo

CRAIG C. BLACK, Director, Los Angeles County Museum of Natural History

ERICH BLOCH (ex officio), Director, National Science Foundation

FREDERICK P. BROOKS, JR., Kenan Professor of Computer Science, University of North Carolina

RITA R. COLWELL, Director, Maryland Biotechnology Institute and Professor of Microbiology, University of Maryland

F. ALBERT COTTON, W.T. Doherty-Welch Foundation Distinguished Professor of Chemistry and Director, Laboratory for Molecular Structure and Bonding, Texas A&M University

THOMAS B. DAY, President, San Diego State University

JAMES J. DUDERSTADT, Vice President for Academic Affairs and Provost, The University of Michigan

ROBERT F. GILKESON, Chairman of the Executive Committee, Philadelphia Electric Company

MARY L. GOOD, President, Engineered Materials Research, Allied-Signal Corporation

JOHN C. HANCOCK, Executive Vice President, Corporate Development and Technology, United Telecommunications, Inc.

JAMES B. HOLDERMAN, President, University of South Carolina

CHARLES L. HOSLER, Vice President for Research and Dean of Graduate School, The Pennsylvania State University

K. JUNE LINDSTEDT-SIVA, Manager, Environmental Sciences, Atlantic Richfield Company

WILLIAM F. MILLER, President and Chief Executive Officer, SRI International

WILLIAM A. NIERENBERG, Director Emeritus, Scripps Institution of Oceanography, University of California at San Diego

KENNETH L. NORDTVEDT, JR., Professor of Physics, Montana State University

JAMES L. POWELL, President, Franklin and Marshall College

NORMAN C. RASMUSSEN, McAfee Professor of Engineering, Massachusetts Institute of Technology

FRANK H.T. RHODES, President, Cornell University

HOWARD A. SCHNEIDERMAN, Senior Vice President for Research and Development and Chief Scientist, Monsanto Company

THOMAS UBOIS, Executive Officer

National Science Board Group on Science & Engineering Indicators—1987

Craig C. Black, *Chairman*, Director, Los Angeles County Museum of Natural History

Charles L. Hosler (ex officio), Vice President for Research and Dean of the Graduate School, Pennsylvania State University

William F. Miller, President and Chief Executive Officer, SRI International

James L. Powell, President, Franklin and Marshall College

K. June Lindstedt-Siva, Manager, Environmental Sciences, Atlantic Richfield Company

**SCIENCE &
ENGINEERING
INDICATORS -
1987**



NATIONAL SCIENCE BOARD

Letter of Transmittal

November 30, 1987

My Dear Mr. President:

In accordance with Sec. 4(j)(1) of the National Science Foundation Act of 1950, as amended, it is my honor to transmit to you, and through you to the Congress, the eighth in the series of biennial *Science Indicators* reports, this time retitled, *Science & Engineering Indicators—1987*.

These reports are designed to display a broad base of quantitative information about U.S. science, engineering, and technology for the use of public and private policymakers in their decisions about these activities.

The actions of Government and industry in recent years demonstrate their recognition of the critical contributions of basic research and advanced technology development to our health, welfare, economic competitiveness, and national security. The quantitative analyses in this report portray these developments in some detail, thereby improving our understanding of the scientific and technological enterprise.

As in previous reports, basic information is provided on U.S. and comparative foreign trends in R&D support and performance, school science and mathematics, human resources for science and technology, technological innovation and trade in high-technology products, and public attitudes toward science and technology. New features of this report include a chapter on "Higher Education for Scientists and Engineers" and an "Overview" section that features the major findings of the report.

I and my colleagues on the National Science Board trust that this report will be of value to your Administration, to the Congress, and to those concerned with science and technology policy.

Respectfully yours,



Roland W. Schmitt
Chairman, National Science Board

The Honorable
The President of the United States
The White House
Washington, D.C. 20500

Contents

	<i>Page</i>
LETTER OF TRANSMITTAL	iii
INTRODUCTION	ix
ACKNOWLEDGMENTS	xi
OVERVIEW	1
CHAPTER 1. PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION	
Highlights	20
Student Achievement and Participation	21
Mathematics Achievement	21
Science Achievement	21
Computer Competence	21
Students Intending to Major in S/E Subjects	22
College-Bound Seniors	23
International Comparisons of Achievement Test Results	24
Top Mathematics Test Scorers	24
Expected Majors of College Freshmen	25
Teacher Characteristics	25
Courses Taken by Science and Mathematics Teachers	26
Teachers' Perceptions of Their Qualifications to Teach	27
Teacher Supply and Qualifications	27
Teacher Reform Movements	29
State Reforms	29
Potential Teachers	30
Certification	31
Teacher Education	31
Higher Education Reforms	31
Federal and Private Sector Programs	31
Student Reform Movements	32
Research on Teachers and Teaching	32
Input-Output Studies	33
Process-Product Studies	33
Elementary and Secondary Mathematics Curricula	33
Eighth Grade	34
Twelfth Grade	34
Textbook Content	35
Student Attitudes toward Mathematics	36
References	36
CHAPTER 2. HIGHER EDUCATION FOR SCIENTISTS AND ENGINEERS	
Highlights	40
Enrollments	41
Undergraduate Enrollments	41
1985 Freshmen	41
Engineering and Technology Enrollments	41
Freshmen Characteristics	41
Graduate Enrollments	41
Part-Time Graduate Enrollments	43
Postdoctorates	43
Enrollments by Gender	43
Enrollments by Racial/Ethnic Status	43
Enrollments by Citizenship	44

Science and Engineering Degrees	44
Overall Degree Trends	44
Time-to-Ph.D.	45
Ph.D.'s by Citizenship	45
S/E Degrees by Gender	45
S/E Graduate Student Support	45
Source of Support	46
Financial Support by Type	46
Support by Gender and Source	46
Institutions of S/E Higher Education	47
The Producers of S/E Doctorates	47
Large Producers of S/E Ph.D.'s	47
"Productive" Producers of S/E Ph.D.'s	48
S/E Higher Education Faculties	48
References	49
CHAPTER 3. SCIENCE AND ENGINEERING WORKFORCE	
Highlights	52
Utilization of Scientific and Technical Personnel	53
Trends in S/E Employment	53
Trends in Science and Technology Activities	54
Sectoral Trends in the S/E Labor Force	55
Industry	55
Educational Institutions	58
Federal Government	58
Other Sectors	58
Demographic Trends: Educational Attainment	59
Bachelor's and Master's Degrees	59
Doctorates	60
Women in Science and Engineering	61
Minorities in Science and Engineering	63
Supply and Demand for S/E Personnel—Labor Market Indicators	64
Labor Force Participation Rates	64
Unemployment Rates	64
S/E Employment Rate	64
S/E Underemployment	64
S/E Underutilization	65
Shortages of S/E Personnel	65
Overview	66
Projected Demand	67
Short-Term Outlook	67
Long-Term Outlook	67
S/E Supply Outlook	68
The S/E Pipeline	68
New Entrants	68
Occupational Mobility	69
Separations	69
Outlook	69
International Employment of Scientists and Engineers	70
References	72
CHAPTER 4. RESOURCES FOR R&D AND BASIC RESEARCH	
Highlights	76
R&D Funding	77
International Comparisons	77
R&D Funding as a Percent of GNP	77
Funding Sources	77
Performers	77
Character of Work	77
Funding for Basic Research and Academic R&D	78
Funds for Academic R&D	78
Sources of Support	78
Forms of Support	78

Proposal Activity	78
Funds for Nonacademic Basic Research	79
FFRDC's and Federal Intramural Laboratories	79
Industrial Basic Research	79
Funding by Fields of Science and Engineering	79
Universities and Colleges	79
Industry	80
Plant and Equipment	80
Facilities Spending	80
Condition of Facilities	81
Facilities Plans	81
Equipment Spending	82
Special Programs	82
Instrument Inventory	83
Maintenance and Repair	84
Instrument Intensity	84
Cross-Institution Collaboration	84
Special Research Resources	84
Supercomputers	85
Collections of Research Materials	85
References	86
CHAPTER 5. ACADEMIC R&D AND BASIC RESEARCH:	
PATTERNS OF PERFORMANCE	
Highlights	88
Institutions	89
Scientists and Engineers in Academic R&D and Basic Research	89
Number of Researchers	90
Women Scientists and Engineers	91
Minority Scientists and Engineers	91
Postdoctoral Positions	92
Retention Rates in Research Careers	92
Employment Sectors	92
Growth Patterns by Field	93
Cross-Sector Interactions	94
Cross-Sector Mobility of Researchers	94
Cross-Sector Coauthorships and Citations	95
University-Industry Contacts	96
Faculty Consulting	97
Research Contacts	97
University Entrepreneurship	97
International Contacts	98
Young Researchers	98
International Collaboration	98
Publications	99
Cross-National Attention	99
A Case Study in International Collaboration	99
References	100
CHAPTER 6. INDUSTRIAL RESEARCH AND	
TECHNOLOGICAL INNOVATION	
Highlights	102
Scientific and Engineering Personnel in Industry	103
Expenditures for Research and Development in Industry	104
Trends in Company Funding	104
Trends in Federal Funding	105
R&D Expenditures and Employment in Individual Industries	105
Patented Inventions	106
Inventors and Owners of Inventions Patented in the United States	106
Patenting by Individual Countries in Various Technical Fields	109
Citations from Patents to Previous Patents	110

Small Business in High Technology	111
Employment in Small High-Technology Enterprises	111
Venture Capital and High-Technology Enterprise	114
Small Business and Biotechnology	115
Technological Innovation in Industry	116
Innovation and Innovative Efforts across U.S. Industry	116
Technological Innovation in Individual Technologies	117
References	119
CHAPTER 7. THE INTERNATIONAL MARKETS FOR U.S. TECHNOLOGY	
Highlights	122
The International Diffusion of Technology	123
International Trade in High-Technology Products	123
International Direct Investment	125
U.S. Direct Investment Abroad	125
Operations of Foreign Affiliates of U.S. Parent Firms	126
Foreign Direct Investment in the United States	128
Patent Licenses and Technology Agreements	130
Technology and U.S. Competitiveness	133
High-Technology Trade Competitiveness	133
Direct Investment and Firm Competitiveness	135
References	137
CHAPTER 8. PUBLIC ATTITUDES TOWARD SCIENCE AND TECHNOLOGY	
Highlights	140
Knowledge, Interest, and Attentiveness Regarding Science and Technology ..	142
Attentiveness to Science and Technology	142
Knowledge of Scientific and Technical Terms	143
Attitudes toward Science and Engineering Education	143
Personal Activities Involving Science and Technology	145
Consumption of Information	145
Use of Computers	146
Perceived Results of Science and Technology	147
Benefits versus Harms from Scientific Research	147
Expectation of Future Scientific and Technological Developments	148
Effect of Science and Technology on Work and Employment Levels	150
Public Acceptance of Science and Technology	152
Attitudes toward Scientists	152
Acceptance of Scientific Thinking	153
Limits and Alternatives to Scientific Thinking	155
U.S. versus Foreign Science and Technology	157
Science and Technology Policy Areas	158
Funding for Basic Research	158
Restriction of Research	158
Government Regulation of Science and Technology	160
Advantages versus Disadvantages of Various Technologies	161
Reactions to Challenger and Chernobyl Accidents	162
Reactions to Space Shuttle Accident	162
Attitudes toward Space Program and Science and Technology Generally ...	163
Attitudes toward Nuclear Power	164
References	165
APPENDIX I. STATISTICAL TABLES	167
APPENDIX II. CONTRIBUTORS AND REVIEWERS	343
SUBJECT INDEX	345

Introduction

This volume is the eighth in the biennial *Science Indicators* series initiated by the National Science Board in 1972. The report has been renamed *Science & Engineering Indicators (S&EI)* to reflect an increased awareness of the complementary roles played by science and engineering research and education in creating both new knowledge and new technological products and processes.

The series provides a broad base of quantitative information about the structure and function of American science and technology in order to inform national policymakers who must allocate resources to these activities.

More specifically, our leaders and policymakers need to know what kinds, levels, and directions of national effort in science and engineering research and education are necessary in order to:

- Produce significant advances across a broad front in the understanding of natural and social phenomena (basic research);
- Foster vigorous inventive activity to produce continuing technological advances (applied research and development);
- Combine understanding and invention in the form of socially useful and affordable products and processes (innovation); and
- Assure an adequate supply of highly trained scientists and engineers to staff the Nation's businesses, schools, and government.

The science, engineering, and technology system is less easy to measure than other major functional areas of our society such as health, agriculture, or the economy. This is in good part due to the nature of its primary output—knowledge and ideas. People create, communicate, and carry ideas; and dollars support people. We can and do track people and dollars. But our methods for measuring science as a body of ideas and its connections with the social and economic order are still unsophisticated. Thus, our indicators remain—for now—largely measures of aspects of science and engineering *as sets of activities*, rather than as *particular bodies of knowledge*.

The elements of the science, engineering, and technology system in America are:

- The human resources, including mainly the working scientists and engineers themselves, but also their technical support and technical managers and entrepreneurs;
- The various organizational settings for the conduct of research and development and technical education;
- The substantive ideas and research methods and strategies embodied in large part in science and engineering literatures;

- The physical infrastructure, including research and teaching facilities and instrumentation with the most advanced capabilities;
- The necessary financial support for all of these elements; and
- Probably the least tangible, a cultural, economic, and legal context supportive of these efforts.

These elements and subelements, while easy to specify in principle, are difficult to describe in practice. Many problematic research issues are involved—for example, choosing definitions and information-gathering methods in terms of their costs and benefits. Even more critical are the problems of tracking and analyzing the interactions among the imperfectly measured elements—the dynamics of the system. Continuing investigation into these questions is a *sine qua non* of improved indicators, and the National Science Foundation (NSF) does provide modest funds for external research projects in this area. (See Program Announcement NSF 85-50.) Descriptions of projects currently under way are available in *Project Summaries: FY 1986* (NSF 86-313).

About one-half of the quantitative information in this report is generated by the national surveys and studies conducted on a continuing basis by the Division of Science Resources Studies (SRS). Detailed reports of these studies are listed in the Division's *Publications List: 1977-1987* (NSF 87-312).

In response to suggestions from a variety of sources, both the substance and format of *S&EI-87* have been modified from previous editions.

- The Overview section has been changed from a purely textual exposition to a set of graphic displays of the report's major findings, accompanied by short descriptive captions and references to the more extensive discussions in the chapters.
- A new chapter, "Higher Education for Scientists and Engineers," focuses on the education and training of scientists and engineers and the roles played by different kinds of higher education institutions.
- To provide more complete coverage of each major topic, the international comparative aspects of each topic have been integrated into the chapters. Significant international comparisons are presented together in the Overview section.
- A discussion of basic research in various settings has been added to the chapter on academic research.
- The chapter containing narrative discussion of selected advances in science has been discontinued on the grounds that these qualitative materials are more appropriately handled elsewhere.

Science & Engineering Indicators—1987 is a collective effort, as can be seen in the following acknowledgments and in Appendix II. Overall responsibility for the report derives from the statutory charge to the National Science Board [Sec. 4(j)(1) of the National Science Foundation Act of 1950, as amended]. A special committee of National Science Board members provided oversight and guidance to the staff of the Science Indicators Studies Group

of the Division of Science Resources Studies, who worked exclusively on the report and the related research. Other SRS members, as well as staff members from other NSF Directorates, aided in manuscript preparation. Numerous external expert reviewers and users helped shape and sharpen the indicators. Overall staff responsibility for the report was assumed by the Directorate for Scientific, Technological, and International Affairs.

Acknowledgments

The National Science Board extends its appreciation to the following members of the National Science Foundation (NSF) who provided primary assistance with the preparation of this report.

Organizational responsibility was assigned to the Directorate for Scientific, Technological, and International Affairs:

Richard J. Green, Assistant Director

The draft manuscript was produced by the Division of Science Resources Studies (SRS) under the guidance of:

William L. Stewart, Director

Leonard L. Lederman, Head, Special Analytical Studies Section¹

Carlos E. Kruytbosch, Director, Science Indicators Studies Group

The manuscript was written by the following NSF staff members:

Lawrence Burton, Science Indicators Studies Group, SRS

Donald E. Buzzelli, Science Indicators Studies Group, SRS

Jason E. Christian, Science Indicators Studies Group, SRS

Susan E. Cozzens, Science Indicators Studies Group, SRS²

R. Keith Wilkinson, Employment Studies Group, SRS

Richard M. Berry, Directorate for Science and Engineering Education

Primary statistical and secretarial support was provided by Theodosia (Dottie) Jacobs, Vellamo Lahti, Eliza Hizell, and Rosa Queen, all staff members of SRS.

The Board expresses its deep regret at the passing of Dr. Robert R. Wright on July 13, 1987. The Board appreciates his significant contribution to the production of six volumes of the *Science Indicators* series during his tenure as Head of the Science Indicators Unit from 1975 to 1985.

The Board is also grateful to the special contributors and to those who reviewed the draft chapters of *Science & Engineering Indicators—1987*, all of whom are listed in Appendix II. Thanks are also due to the staff of the NSF Printing Office and to the editors at Evaluation Technologies, Incorporated for their assistance in the production of this complex document.

¹From August 1986.

²Through July 1986.

**overview
of
U.S. Science and Technology**

Overview of U.S. Science and Technology

SYNOPSIS

By all conventional standards, U.S. research and development (R&D) has enjoyed vigorous growth in recent years. The two major sources of R&D funds—the Federal Government and industry—have been driven by the twin concerns of national security and economic competitiveness to maintain a fast pace of R&D investment.

In 1986 the U.S. research and development enterprise entered its 10th year of uninterrupted real expansion with a healthy 5.9 percent constant-dollar increase over 1985. The basic research component of R&D also continued to expand, although at a slightly lower rate (5.4 percent between 1985 and 1986). Similar continuing growth patterns are evident in the employment of science and engineering (S/E) personnel in the economy, and in R&D as a percentage of gross national product (GNP). S/E enrollments and degrees have also shown small upward trends although, as discussed below, this may be the result of the flow of foreign citizens into S/E fields, especially at the graduate level.

In several areas relevant to science and technology (S/T), the U.S. can be seen as in a "holding pattern" over the past decade. For example, in the area of technological innovation, the number of patents granted to U.S. organizations or individuals has fluctuated within a fairly narrow range over the period. The U.S. has also continued to maintain both its share of world international trade in high-technology goods and world scientific publications in all fields with only a slight drop in these over the decade.

Matters for concern appear at both the input and output ends of the S/T spectrum—the condition of pre-college science and mathematics education, and the ability of U.S. corporations to compete in world markets for high-technology goods.

There is no evidence of an upturn in the low performance levels of U.S. schoolchildren on science and mathematics achievement tests, nor in their continuing relatively poor performance on such tests in comparison with some other industrial countries. U.S. State and local school jurisdictions have recently been investing significant resources in this problem area, but it is apparently too soon to see any results.

Compounding the "input issue," are the demographics of the 1990's. The shrinking of the college-age population suggests difficulties in maintaining an adequate flow of new science and engineering personnel unless young people—especially minorities and women—can be induced to increase their participation rates in college science and engineering programs.

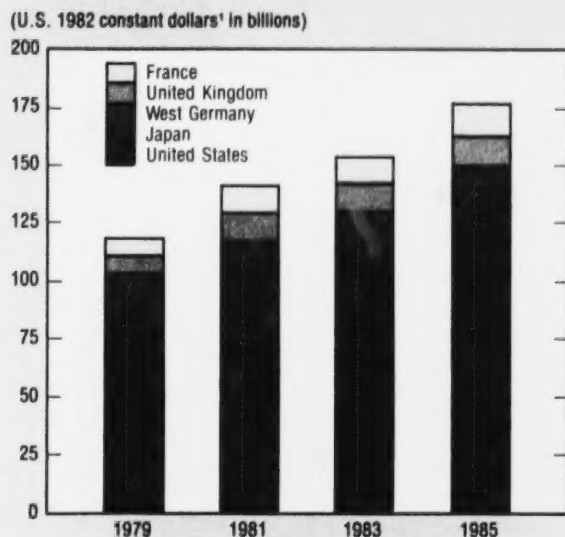
At the output end, in 1986 the U.S. balance of trade in high-technology goods became—for the first time—a negative, thus intensifying the search for measures to improve U.S. international economic competitiveness.

The following displays summarize the major findings delineated in the various chapters of *Science & Engineering Indicators—1987*. Each data display is referenced to the discussion in the appropriate chapter.

R&D INVESTMENTS IN A WORLD CONTEXT

In the world context, the U.S. makes by far the largest investments in R&D of any Western country. (See figure O-1.) The U.S. spends more on R&D than the next four largest countries combined. Despite the difference in

Figure O-1.
Expenditures on research and development
in selected countries



¹Foreign currency data are converted into U.S. dollars using current purchasing power parities. The data are then converted to 1982 dollars using the U.S. GNP deflator. See appendix table 4-1 and p. 77. Science & Engineering Indicators — 1987

absolute size, the U.S. invests approximately the same proportion of its GNP in R&D as do the other major noncommunist industrialized countries. The display also shows that in recent years, the R&D growth rates of Japan and West Germany have been rising faster than that of the U.S., enabling these countries to match U.S. R&D spending as a percent of GNP. (See figure O-2.)

The data in figure O-2 show that in recent years other nations have caught up with the U.S. in R&D investments. However, the nature of the investments must also be taken into account. If only nondefense R&D is considered, West Germany and Japan have been ahead of the U.S. for 15 years, and their rate of civilian R&D investment as a percent of GNP has been rising faster than that of the U.S. for the past 5 years. (See figure O-3.)

Figure O-2.
R&D expenditures as a percent of GNP, by country

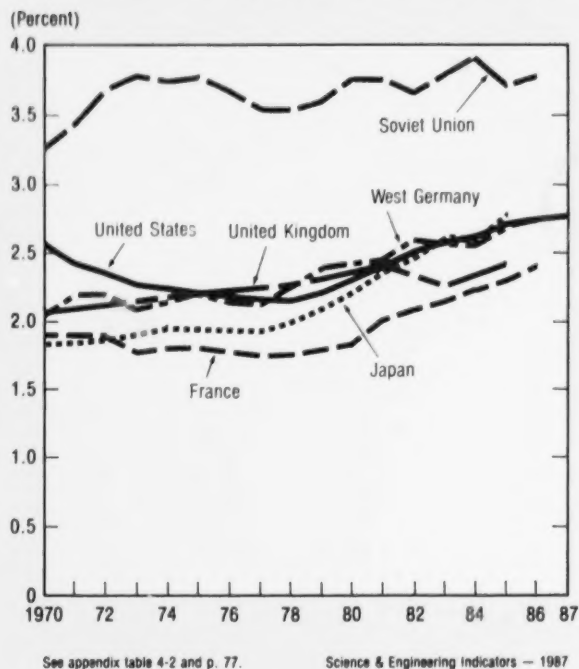
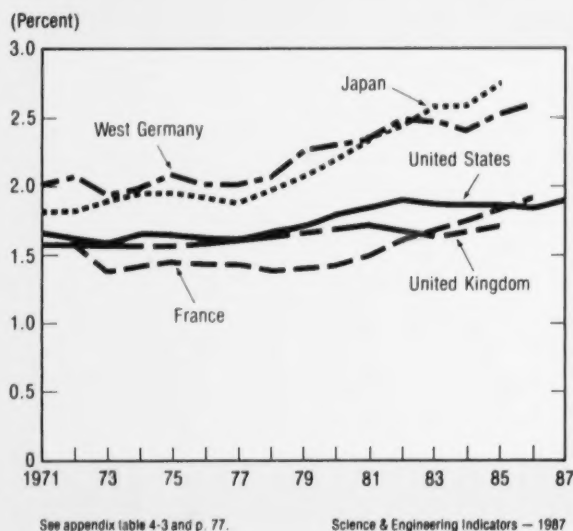


Figure O-3.
Non-defense R&D expenditures as a percent of GNP,
by country



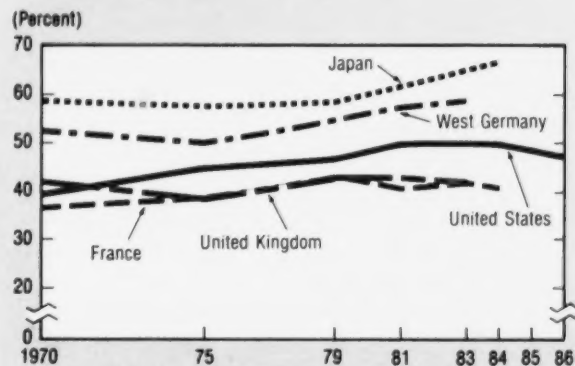
As the share of national R&D effort a country devotes to defense-related activities increases, the share of resources it devotes to business-related activities decreases. Figure O-4 shows a similar pattern to figure O-3—in West Germany and Japan, a significantly higher proportion of national R&D investments derive from business sources.

Continued growth is observed in U.S. R&D expenditures, both in constant dollars (figure O-5) and as a percentage of GNP—2.76 percent in 1986, the highest level since 1968.

In recent years, development funds have grown at a faster rate than has support for basic or applied research.

A breakdown of Federal defense and nondefense R&D by character of work highlights the defense development buildup, and also the increasing growth of basic research in Federal nondefense R&D. (See figure O-6.)

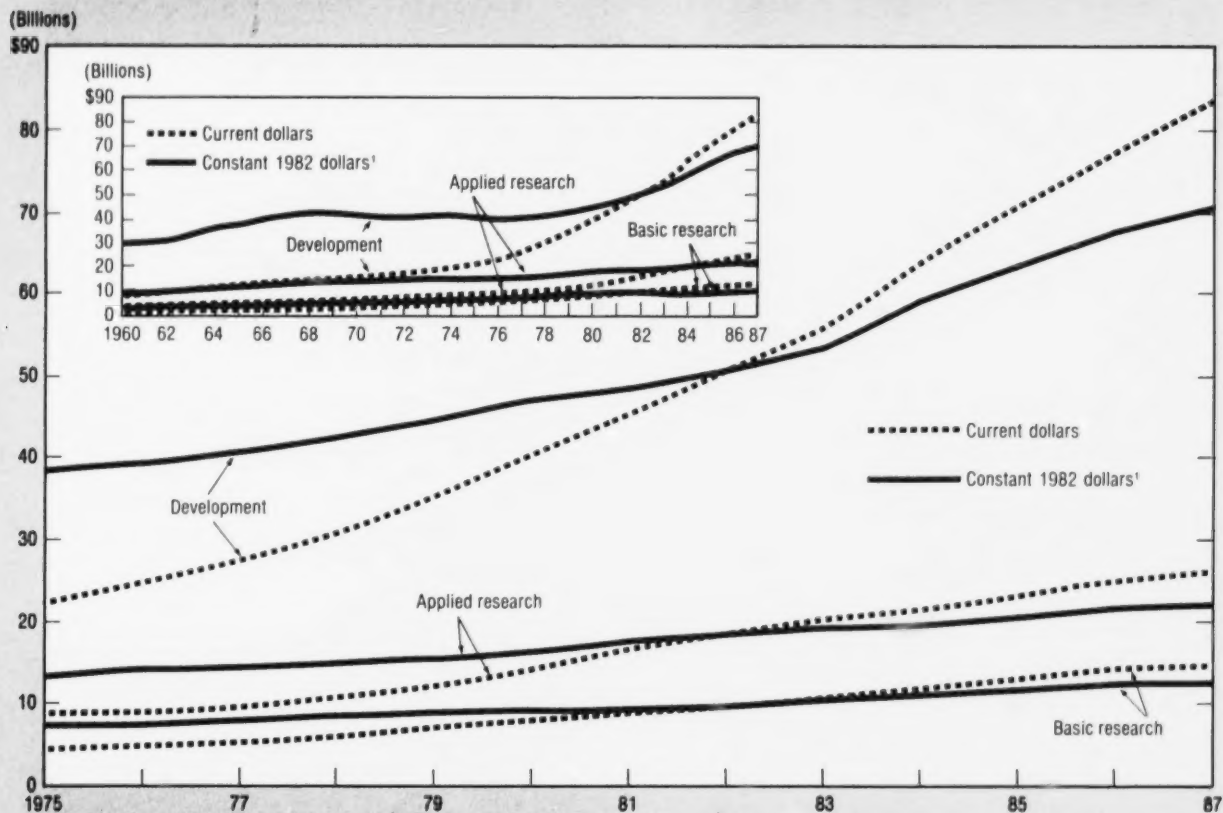
Figure O-4.
Percent of total national R&D expenditures
derived from business sources



See appendix table 4-1 and p. 77.

Science & Engineering Indicators — 1987

Figure O-5.
National R&D expenditures by character of work



¹GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

Note: Estimates are shown for 1985, 1986 and 1987

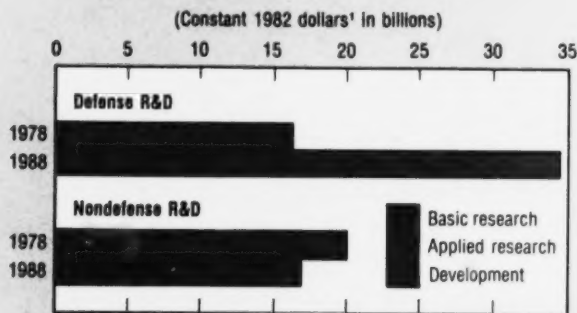
See appendix table 4-6 and p. 77.

Science & Engineering Indicators — 1987

HUMAN RESOURCES

Figure O-6.

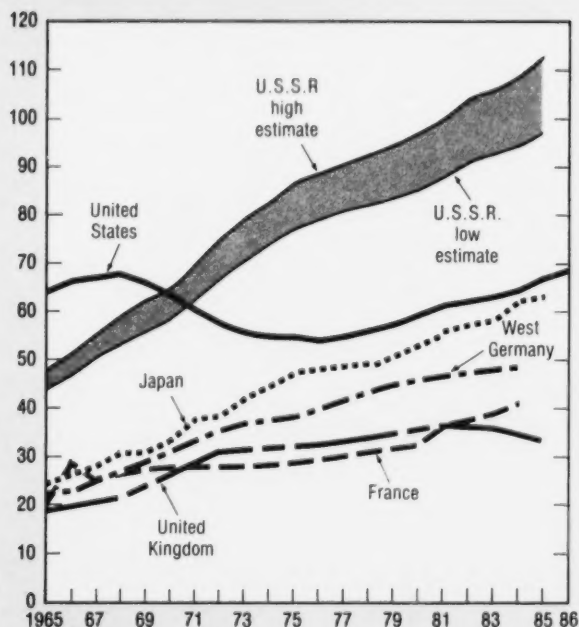
Relative changes in Federal obligations for defense and nondefense R&D by character of work in constant 1982 dollars¹



¹GNP implicit price deflators used to convert current dollars to constant 1982 dollars. See appendix table 4-37 and p. 77. Science & Engineering Indicators — 1987

Figure O-7.

Scientists and engineers engaged in R&D per 10,000 labor force population



See appendix table 3-17 and p. 71.

Science & Engineering Indicators — 1987

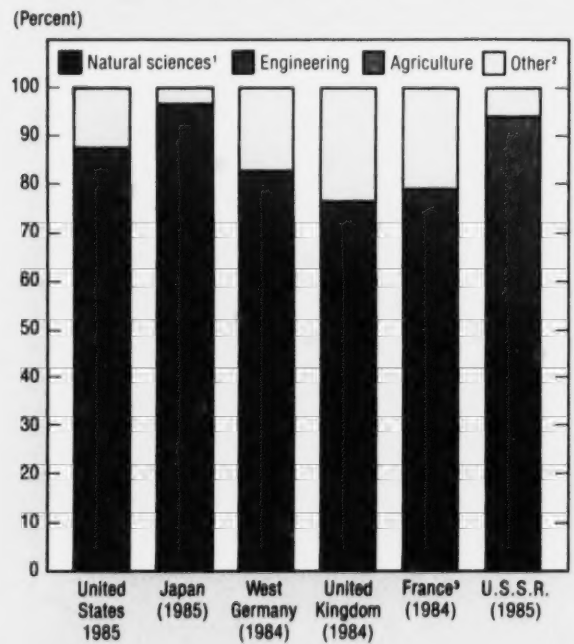
International Comparisons

Compared with other advanced industrial countries, the U.S. proportion of scientists and engineers in the labor force who are engaged in R&D has been growing faster than Western European countries, but slower than Japan. (See figure O-7.) Because of the great differences between the Soviet system and the market economies, comparisons with Soviet data require caution.

Advanced industrial countries vary considerably in the proportion of all first academic degrees which are in S/E fields, as well as in the relative proportions of natural scientists and engineers. (See figure O-8.) Soviet and Japanese degrees are heavily weighted towards engineers, while in the United Kingdom natural science degrees outnumber engineering degrees.

Figure O-8.

First university degrees by field and country



¹Includes physical sciences, biological sciences, and mathematics.

²Includes social sciences.

³Degrees for France are maîtrise degrees, plus engineering degrees. French agricultural sciences are included in natural science.

See appendix table 3-23 and p. 71.

Science & Engineering Indicators — 1987

S/E Employment in the U.S.

The employment of scientists and engineers continues to grow as a percentage of the total U.S. labor force. (See table O-1.)

Scientists and engineers have grown more rapidly than several other aspects of the economy—such as total employment and GNP. (See figure O-9.)

There are about 10 percent more employed engineers than scientists in the S/E labor force; S/E distribution by field is shown in figure O-10.

Table O-1. Employed scientists and engineers as a percent of total U.S. employment

Year	Percent
1976	2.4
1978	2.5
1980	2.6
1982	2.9
1984	3.3
1986	3.6

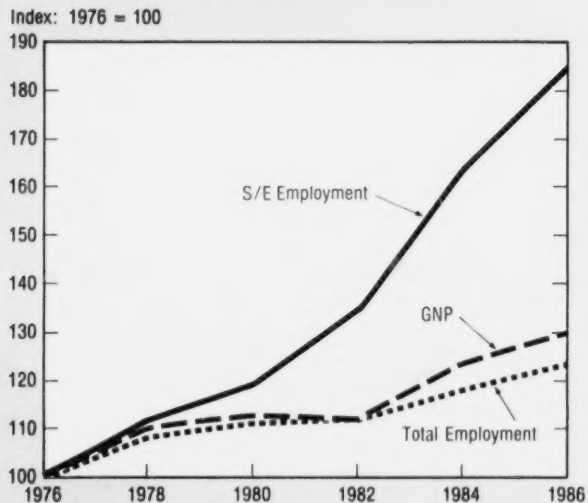
SOURCES: Based on National Science Foundation, *U.S. Scientists and Engineers: 1984*; *Economic Report of the President, 1987*, pp. 282; National Science Foundation, Division of Science Resources Studies, unpublished data

See appendix table 3-2 and p. 53.

Science & Engineering Indicators—1987

Figure O-9.

Relative growth of selected economic indicators

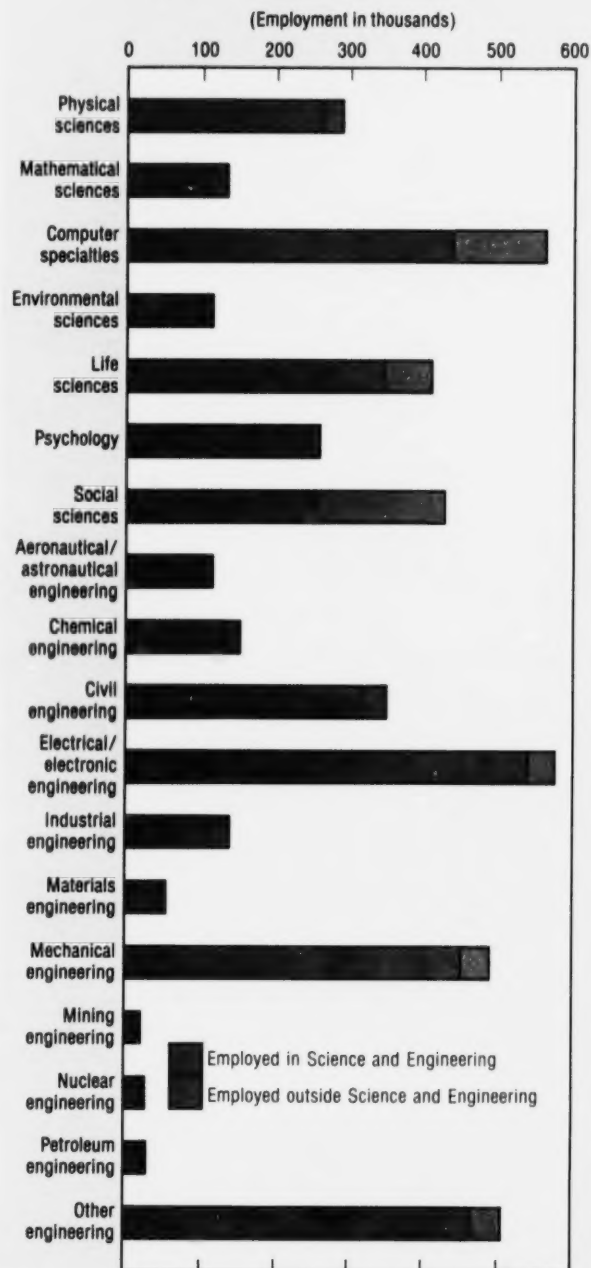


See appendix table 3-3 and page 53.

Science & Engineering Indicators — 1987

Figure O-10.

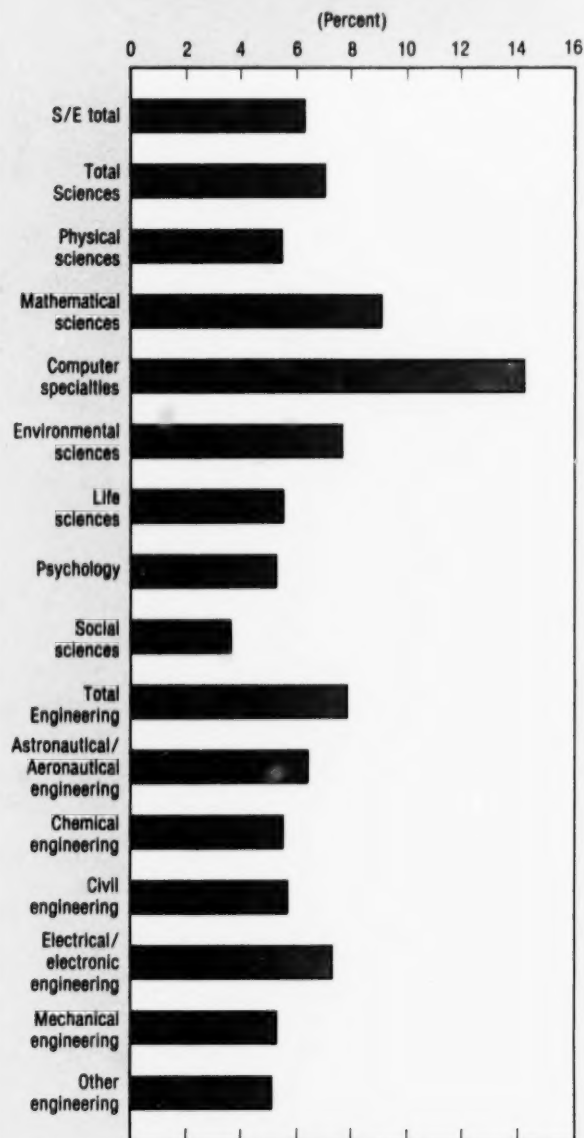
Scientists and engineers employed in S/E jobs and in non-S/E jobs, by field: 1986



See appendix table 3-1 and p. 53. Science & Engineering Indicators — 1987

S/E relative growth rates are shown in figure O-11. The most remarkable recent trend has been the rapid growth of computer specialists at all levels of education.

Figure O-11.
Employed scientists and engineers, average
annual growth, by field: 1976 to 1986



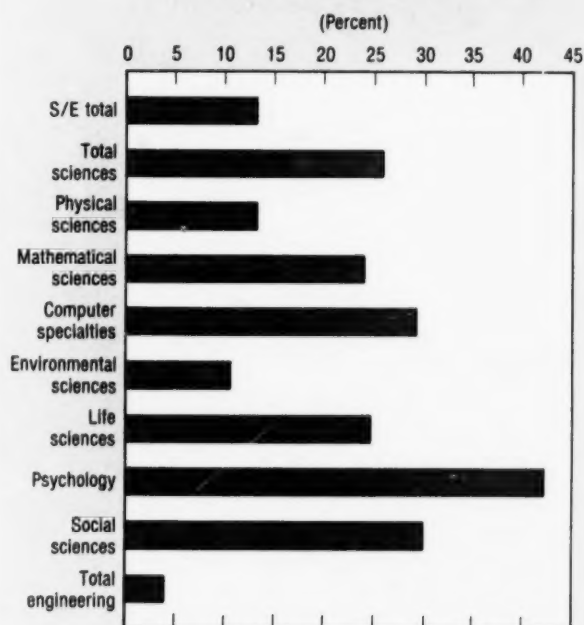
See appendix table 3-1 and pp. 53, 54.

Science & Engineering Indicators — 1987

Women and Minorities in S/E

Employment of women and minorities has increased rapidly, but they continue to be underrepresented in science and engineering. Women constituted less than 4 percent of all engineers and nearly 25 percent of employed scientists. They were more heavily represented in some fields than others. (See figure O-12.)

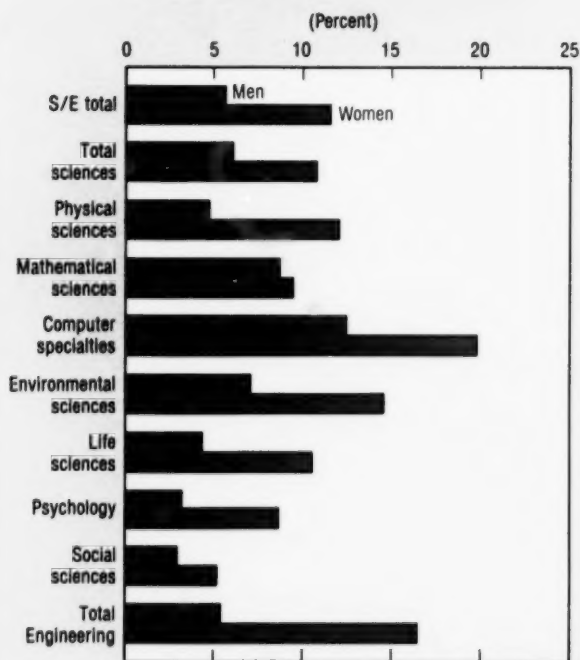
Figure O-12.
Women as percent of total employed scientists
and engineers in S/E fields: 1986



See appendix table 3-1 and p. 62. Science & Engineering Indicators — 1987

The S/E fields enjoying the most rapid increases in employment of women are shown in figure O-13. Again, computer specialists show remarkable growth.

Figure O-13.
Average annual growth rates of employed scientists and engineers by S/E field and sex: 1976-1986

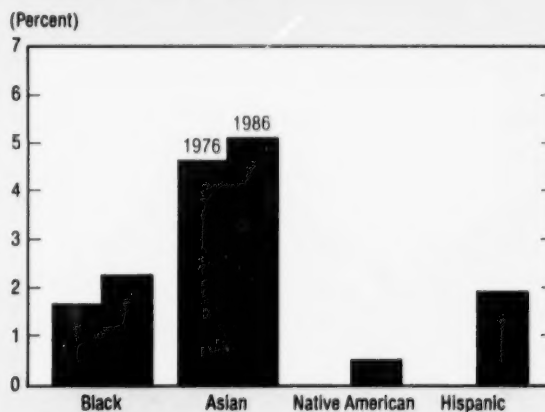


See appendix table 3-1 and p. 62. Science & Engineering Indicators — 1987

Blacks and Hispanics remain underrepresented in S/E jobs, although blacks made significant gains over the decade. (See figure O-14.) Recent data on enrollment of U.S. blacks and Hispanics in graduate S/E degree programs show level or declining participation (see chapter 2, "Higher Education for Scientists and Engineers," p. 43), suggesting slow future growth in minority S/E employment.

Asian-Americans have increased their share of S/E jobs from 5 percent to 6 percent; this is far greater than their distribution in the population.

Figure O-14
Employment of minority scientists and engineers as a percentage of total employment of scientists and engineers



See appendix tables 3-21 and pp. 63, 91.

Science & Engineering Indicators — 1987

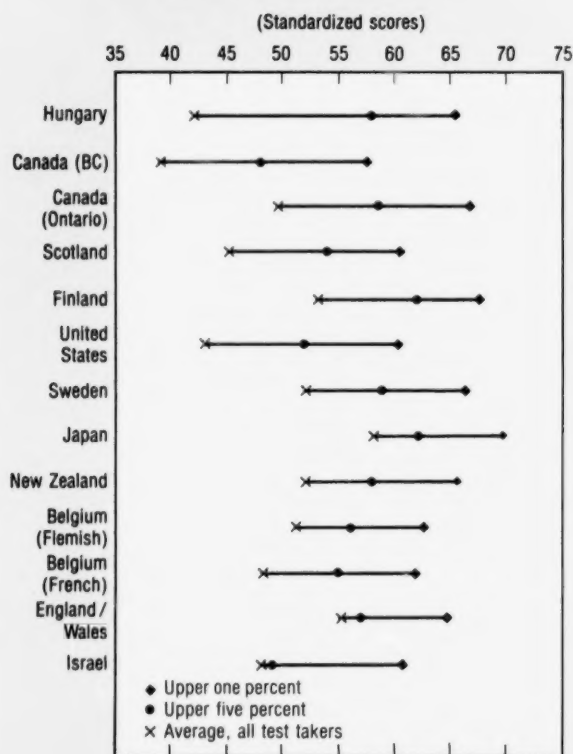
Precollege Education

In a series of international comparative studies, U.S. college preparatory mathematics students scored lower on achievement tests than did their counterparts in most of the countries studied. (See figure O-15.)

Since 1969, the National Assessment of Educational Progress studies have tracked the achievement of national samples of 9-, 13-, and 17-year-olds on mathematics and science tests. Between 1969 and 1977 performance on these tests declined among all age groups, but since 1977 there have been no statistically significant changes in the scores for the whole population of children.

Figure O-15.

Achievement in functions and calculus of the top 1% and 5% of 12th grade students, by country: 1981/82

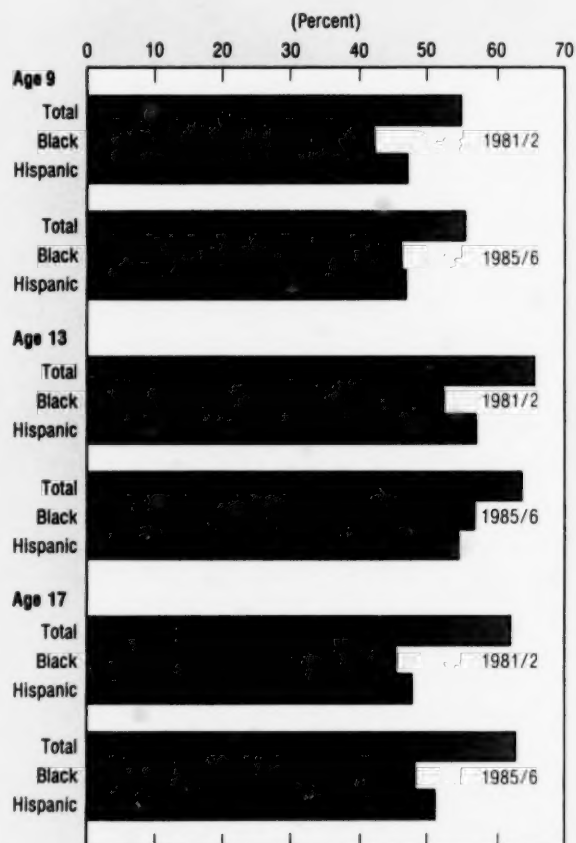


Note: Countries are arranged in decreasing order descending from top to bottom of the proportion of students enrolled in advanced mathematics programs. See appendix table 1-6 and p. 24. Science & Engineering Indicators — 1987

Recently, however, some interesting shifts have occurred among specific groups. Between 1981 and 1986, black children of all ages registered significant test score gains in both science and mathematics. In the 1985/6 test, black 13-year-olds outscored Hispanic 13-year-olds for the first time in both subject matters. (See figures O-16 and O-17.)

Figure O-16.

Achievement scores in mathematics, by age, race, and year

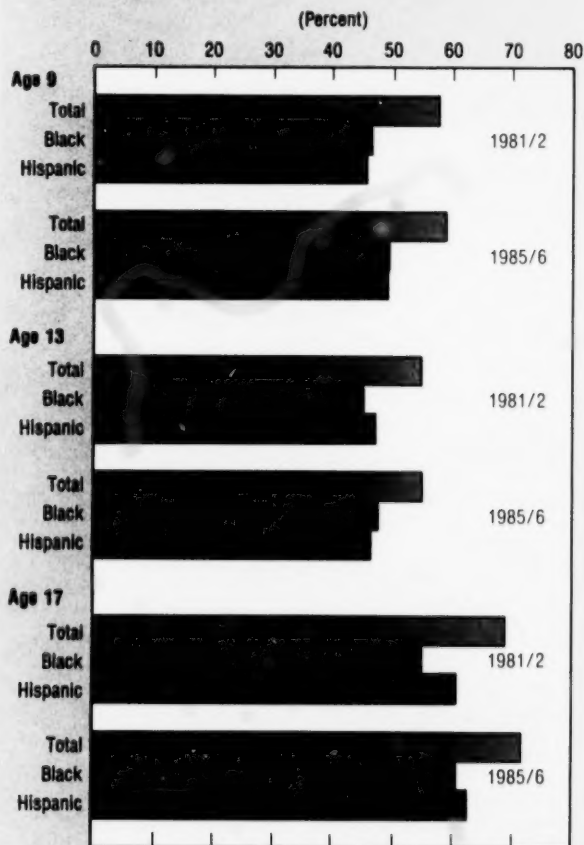


See appendix table 1-1 and p. 21.

Science & Engineering Indicators — 1987

Further, 17-year-olds from all ethnic groups showed small overall gains in both science and mathematics scores. The improvements in mathematics are believed to be related to increased enrollments in intermediate and advanced mathematics courses.

Figure O-17.
Achievement scores in science, by age,
race, and year



See appendix table 1-2 and p. 21.

Science & Engineering Indicators — 1987

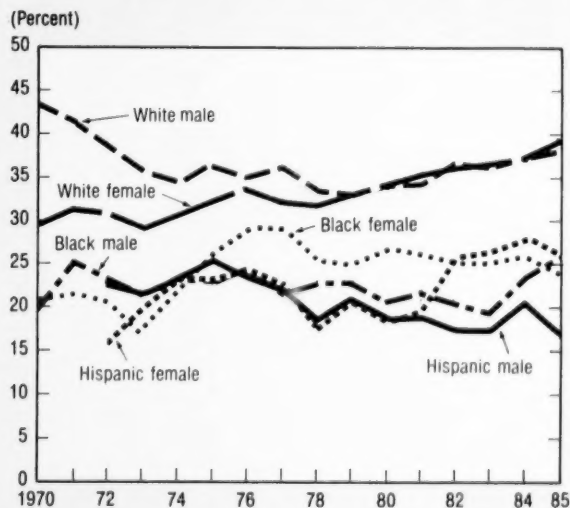
Higher Education

Increases of 5 to 6 percentage points in the college-going rates for U.S. 18- to 21-year-olds are observable over the past 5 years. These increases in the college-going rates of some groups—especially women—have kept total enrollments on the undergraduate level sufficiently high to compensate for the declining size of the 18-year-old population which began in 1979. (See figure O-18.)

The past decade's rapid growth of engineering and computer science students has ended. From 1982-86, there was a dramatic decline in computer science as a freshman major and a smaller decline in engineering. (See figure O-19.)

Parallel declines are seen in freshman choices of these areas as probable future occupations.

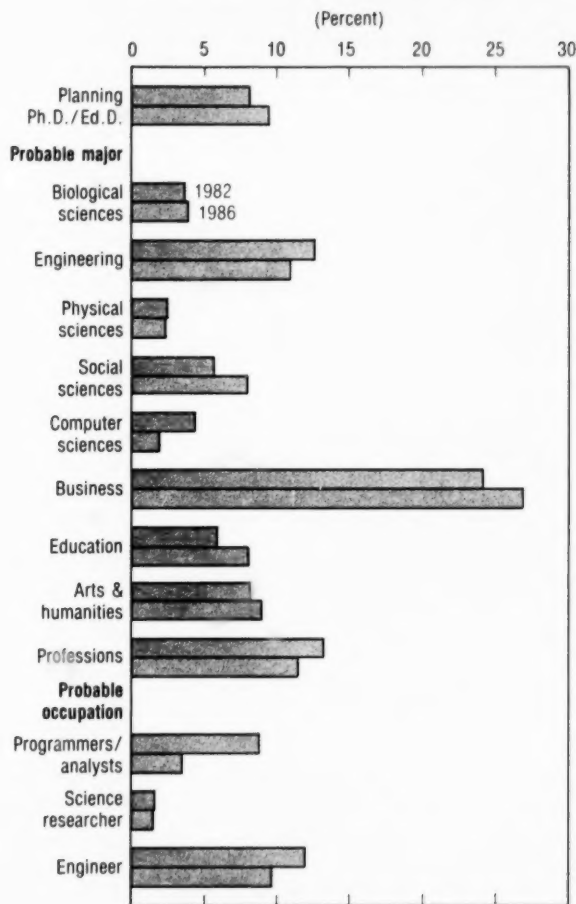
Figure O-18.
College-going rates of 18-21 year olds, by selected
race and gender



See appendix table 2-1 and pp. 41 and 44.

Science & Engineering Indicators — 1987

Figure O-19.

Freshmen plans: 1982 and 1986

See table 2-2 on p. 42

Science & Engineering Indicators — 1987

S/E degrees at all levels increased from 1982-85: bachelor's degrees increased by 6 percent, master's by 4 percent, and doctorates by nearly 8 percent. (See table O-2.)

Engineering, mathematics, and computer science contributed the greatest increases at the bachelor's and master's degree levels, with other sciences registering either declines or no growth. Doctoral degrees increased in all fields, led by engineering and computer science.

Table O-2. Science and engineering degrees, by level and field

Degree level and field	1982	1983	1984	1985	1986
Total S/E bachelor's	302,118	307,225	314,666	321,739	NA
Physical sciences	24,372	23,497	23,759	23,847	NA
Engineering	67,791	72,954	76,531	77,871	NA
Mathematics	11,708	12,557	13,342	15,267	NA
Computer sciences	20,431	24,678	32,435	39,121	NA
Life sciences	65,041	63,237	59,613	57,812	NA
Psychology	41,539	40,825	40,375	40,237	NA
Social sciences	71,236	69,477	68,611	67,574	NA
Total S/E master's	57,025	58,868	59,569	61,278	NA
Physical sciences	5,526	5,288	5,568	5,802	NA
Engineering	18,594	19,721	20,352	21,206	NA
Mathematics	2,731	2,839	2,749	2,888	NA
Computer sciences	4,935	5,321	6,190	7,101	NA
Life sciences	9,824	9,720	9,330	8,757	NA
Psychology	7,849	8,439	8,073	8,481	NA
Social sciences	7,566	7,540	7,307	7,043	NA
Total S/E doctor's	17,626	17,932	18,069	18,261	18,792
Physical sciences	3,351	3,439	3,459	3,534	3,679
Engineering	2,646	2,781	2,913	3,167	3,376
Mathematics	720	701	698	688	730
Computer sciences	220	286	295	311	399
Life sciences	4,841	4,749	4,869	4,882	4,790
Psychology	3,158	3,309	3,230	3,072	3,071
Social sciences	2,690	2,666	2,608	2,608	2,747

SOURCE: National Science Foundation, Science & Engineering Education Sector Studies Group, unpublished data

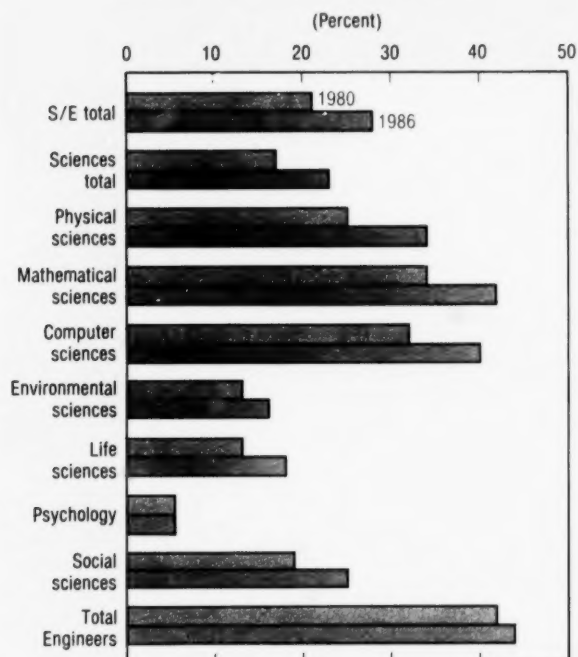
See figure 2-3, appendix tables 2-9 and 2-10 and pp. 44-45.

Science & Engineering Indicators—1987

Over the past decade, foreign students have increased significantly in all S/E fields as a proportion of all graduate students enrolled in U.S. doctoral-granting institutions. (See figure O-20.) The trend is strongest in the mathematical, physical, and computer sciences.

Graduate degrees granted to foreign citizens have also increased; in 1984, for example, 52 percent of all U.S. engineering Ph.D.'s were awarded to foreign citizens.

Figure O-20.
Foreign students as a percent of full-time graduate enrollment, by field of study



Note: Doctorate-granting institutions only.

See appendix table 2-4 and p. 44. Science & Engineering Indicators — 1987

KNOWLEDGE CREATION AND APPLICATION

The relative strength of U.S. basic and applied research is indicated by the share of articles written by U.S. authors in the world's leading S/E journals. Over the past decade, the U.S. has more or less maintained this share, with some decreases in biology and mathematics. (See table O-3.)

The data in figure O-21 suggest the increasing relevance of foreign scientific work to U.S. science and engineering research. Between 1974 and 1984, there were significant increases across all S/E fields in the percentage of all references in U.S.-authored articles to non-U.S. articles.

Since 1976, U.S. inventors have been granted around 40,000 patents a year. U.S. patents granted to foreign inventors, however, increased by one-third during the same period. (See figure O-22.) Japanese inventors were by far the most active in increasing their U.S. patenting.

Table O-3. U.S. share of world scientific and technical articles¹ by field

Field ²	1973	1981 ³	1984 ³
	Percent		
All fields	38	35	35
Clinical medicine	43	40	41
Biomedicine	39	39	39
Biology	46	38	37
Chemistry	23	20	21
Physics	33	28	27
Earth and space sciences	47	42	41
Engineering and technology	42	41	40
Mathematics	48	38	37

¹ Based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the *Science Citation Index Corporate Tapes* of the Institute for Scientific Information.

² See appendix table 5-27 for the subfields included in these fields.

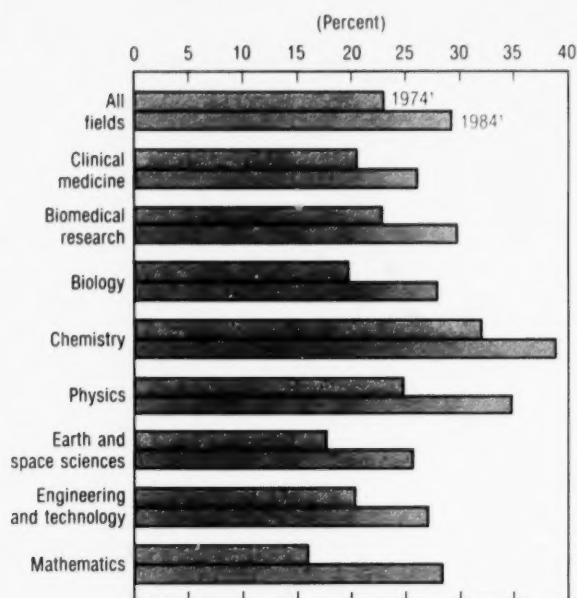
³ Uses over 3,500 of the influential journals carried on the 1981 *Science Citation Index Corporate Tapes* of the Institute for Scientific Information. See appendix table 5-26 and p. 99.

Science & Engineering Indicators—1987

RESEARCH

Figure O-21.

U.S. references to foreign articles, as a percent of all references in U.S. authored articles

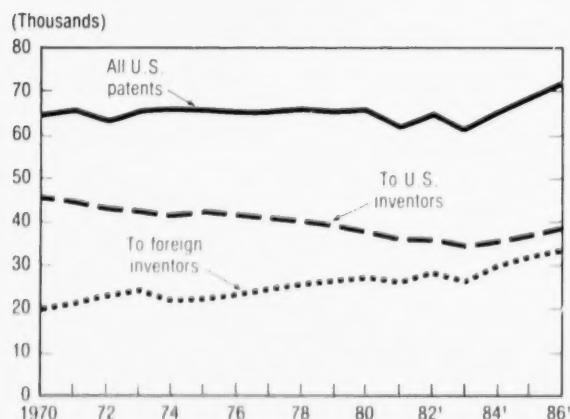


¹Year of publication of articles in which references are found.

See appendix table 5-28 and p. 99 Science & Engineering Indicators — 1987

Figure O-22.

U.S. patents granted, by nationality of inventor and date of application



¹Estimates are shown for 1982-86.

See appendix table 6-8 and p. 107

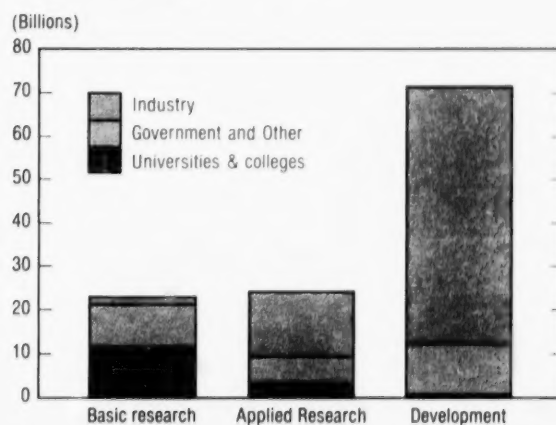
Science & Engineering Indicators — 1987

The distribution of performance of basic and applied research and development among the institutional sectors in the U.S. varies greatly. (See figure O-23.) Measured in dollars, the academic sector performs slightly less than one-half of all basic research, about 10 percent of all applied research, and less than 1 percent of development. Industry is the mirror image of academia, performing four-fifths of all development work, more than three-fifths of applied research, and about one-fifth of all basic research. The sector encompassing the Federal Government (including Federally funded R&D centers) and other performers accounted for about one-third of all basic research, a little more than one-third of all applied research, and about one-sixth of all development activities.

Academic R&D has grown significantly over the past decade—55 percent between 1976 and 1986 in constant dollars. (See figure O-24.) While the overall pattern of academic research has not changed markedly, there have been some significant shifts among fields. Engineering research has increased its share of the total by about 3 percent, and the broad group of physical sciences has claimed an additional 2 percent over the decade. The life sciences lost a 1-percent share, while the biggest losses of total share were incurred by the social and psychological sciences and other sciences, which dropped by 4 percent.

Figure O-23.

Basic and applied research and development, by sector: 1985

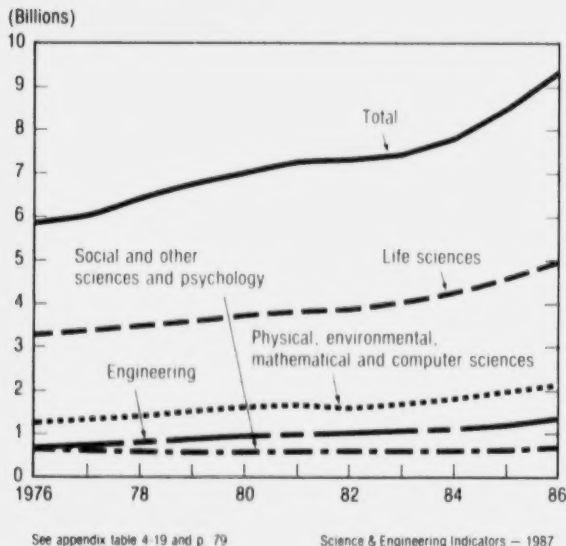


See appendix table 4-7 and p. 77

Science & Engineering Indicators — 1987

Figure O-24.

Expenditures for academic research and development, by field



The Nation is currently experiencing an upsurge of capital spending for academic science and engineering, although the overall constant-dollar expenditures in recent years remain less than one-half their 1968 peak levels. (See figure O-25.)

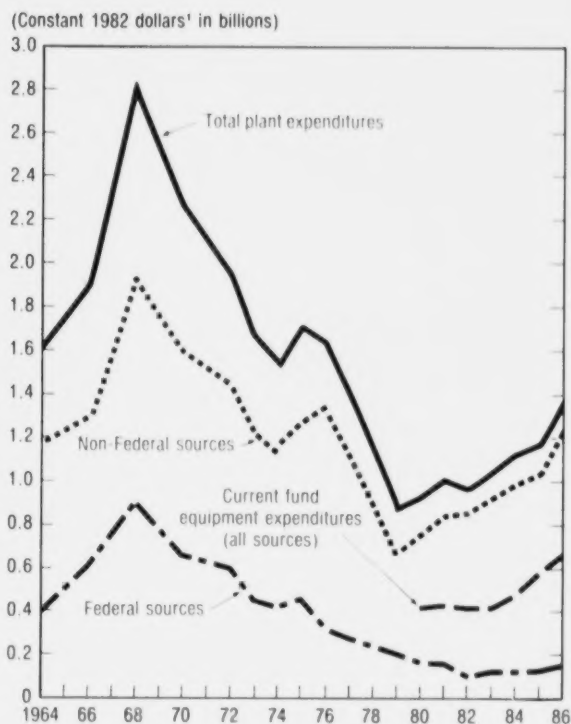
Federal sources have continued to decline as a percentage of total capital expenditures for academic S/E, providing 11 percent of the total in 1985—their lowest percentage in more than 2 decades.

According to a 1986 survey of doctorate-granting research universities, the bulk of support for new S/E capital construction in progress is coming from non-Federal sources such as State Governments (40 percent), funds from tax-exempt bonds (30 percent), and private donations or endowments (14 percent).

Current fund expenditures for research equipment at universities and colleges increased by 80 percent between 1980 and 1985. (See figure O-25.) Funds from all sources grew at approximately the same rate, but—unlike the pattern for facilities spending—nearly two-thirds of the equipment funds came from Federal Government agencies.

Figure O-25.

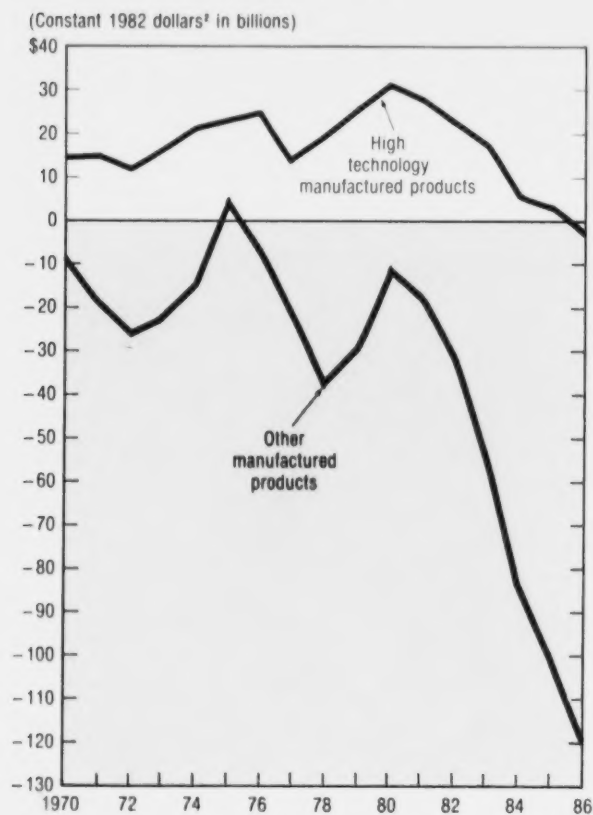
Plant and equipment expenditures in academic S/E, by source of funds



U.S. High-Technology Performance in International Markets

Figure O-26 depicts the trend in the U.S. trade balance in high-technology and other manufactured product groups. U.S. trade in high-technology goods has maintained a positive—though declining—trade balance during the past 15 years. In 1986, for the first time, the U.S. balance of trade in high-technology goods dipped into the negative. Other manufactured goods have had a negative and still declining balance of trade.

Figure O-26.
U.S. trade balance¹ in high-technology and other manufactured product groups



¹Exports less imports

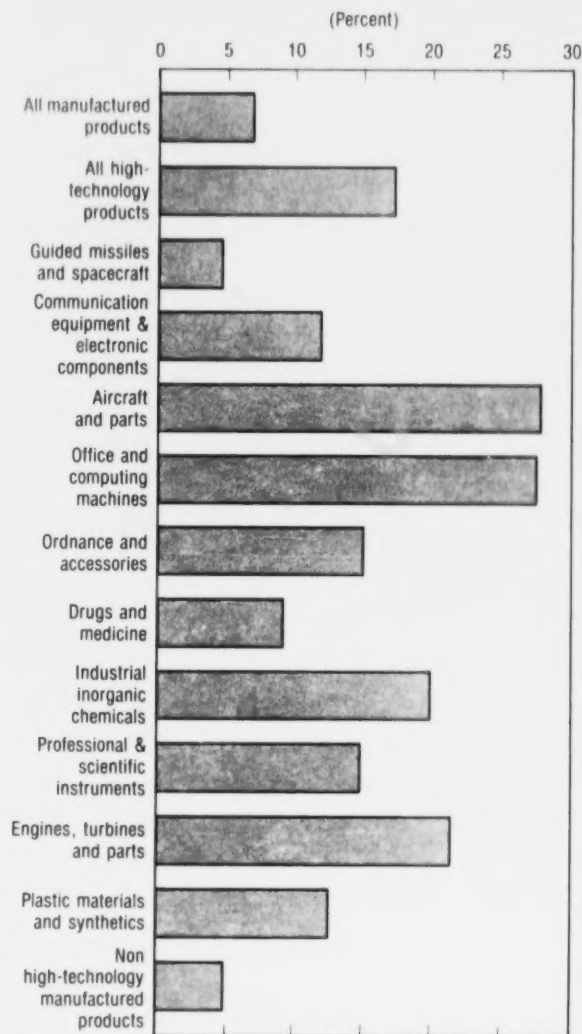
²GNP implicit price deflators used to convert current dollars to constant 1982 dollars

See appendix table 7-1 and p. 124

Science & Engineering Indicators — 1987

The importance of foreign markets to a number of U.S. high-technology industries is shown in figure O-27. In several product fields, more than one-quarter of total shipments is exported.

Figure O-27.
U.S. exports as a percent of shipments, high-technology products, 1985



See appendix table 7-2 and p. 124

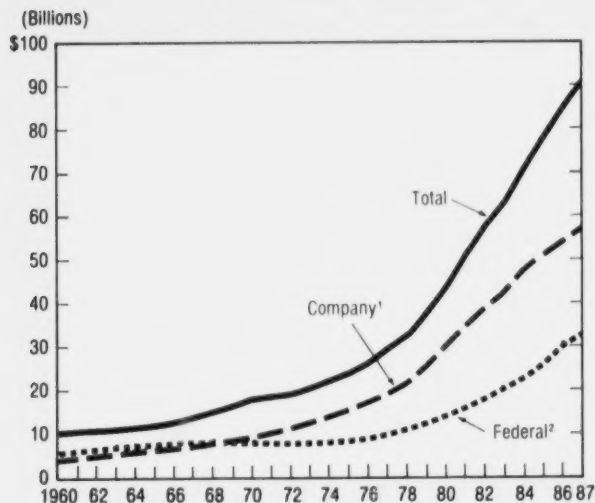
Science & Engineering Indicators — 1987

S/T in U.S. Industry

In 1986, U.S. industry supplied 50 percent of the country's R&D funds, and performed 73 percent of the total R&D. As figure O-28 shows, industry's funding of its own R&D activities has been rising at a faster rate than Federal funding for industrial R&D for almost a decade. As figure O-29 dramatically illustrates, most of this increase has been occurring in the high-technology manufacturing industries.

In the U.S., large corporations perform the bulk of industrial R&D, and manufacture most of the high-technology products. Small high-technology businesses, however, introduce a disproportionate amount of new high-technology products, especially in relation to their R&D expenditures. (See figure O-30.)

Figure O-28.
Expenditures for industrial R&D by source of funds



¹Includes all sources other than the Federal Government.

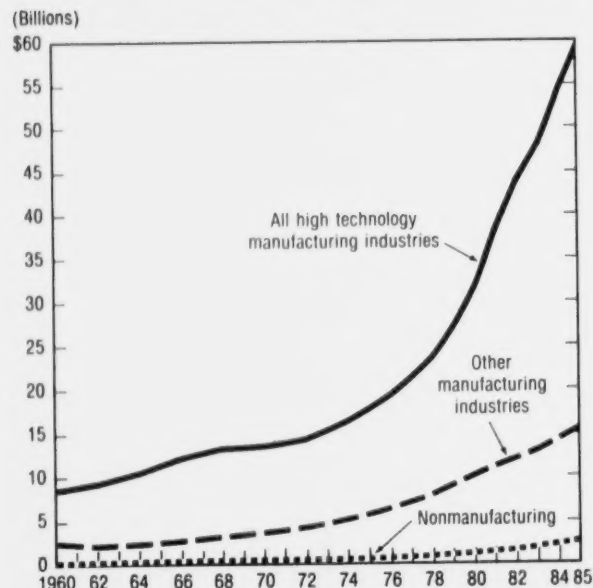
²Includes Federally Funded Research and Development Centers administered by industry.

Note: Preliminary data are shown for 1985 and estimates for 1986 and 1987.

See appendix table 6-2 and p. 104.

Science & Engineering Indicators — 1987

Figure O-29.
R&D expenditures, by industry group

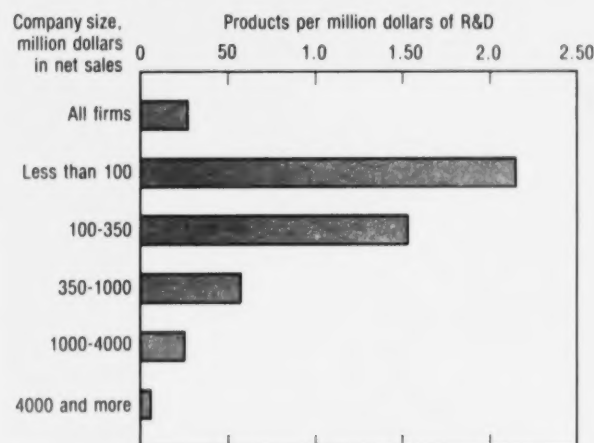


Note: Data include Federally Funded Research and Development Centers administered by industry.

See appendix table 6-3 and p. 105.

Science & Engineering Indicators — 1987

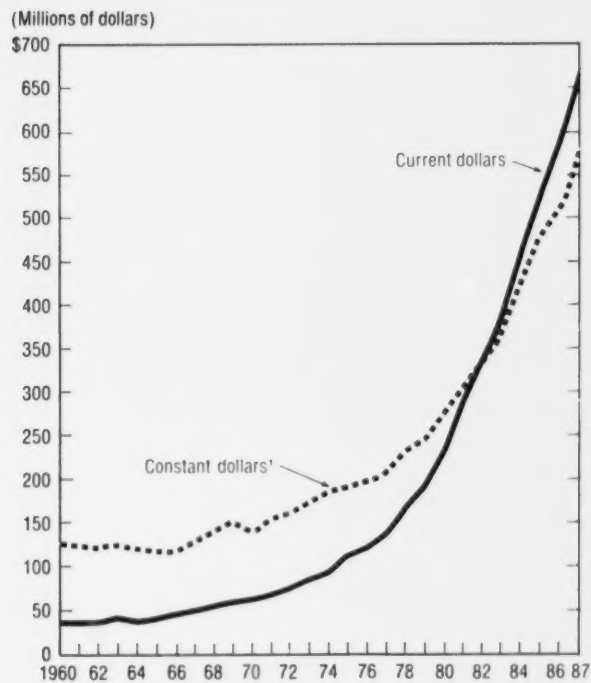
Figure O-30.
New products introduced in 1985,
per million dollars of R&D



See appendix table 6-20 and p. 116. Science & Engineering Indicators — 1987

One of the most striking changes in R&D funding patterns in the past decade has been industry's support of university research. Figure O-31 shows that this trend is continuing apace, although it only just exceeds 5 percent of university R&D.

Figure O-31.
Industry expenditures for R&D in colleges and universities



¹GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

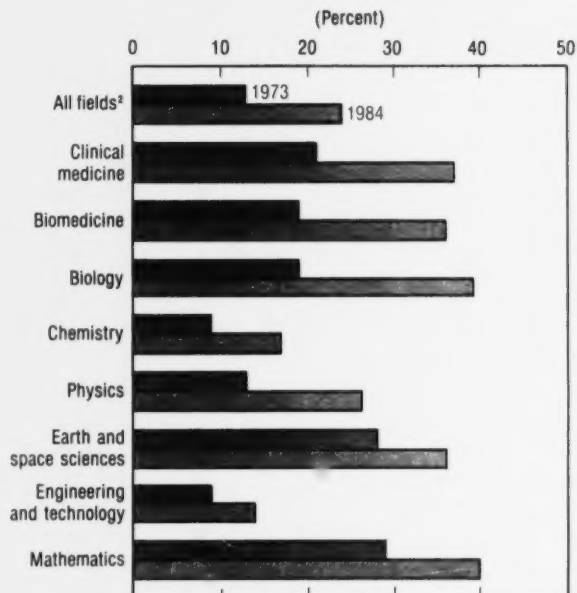
Note: Estimates are shown for 1986 and 1987.

See appendix table 4-10 and p. 78

Science & Engineering Indicators — 1987

The increasing intensity of the university-industry research relationship is reflected in the increases in coauthorship of scientific articles by industry and university scientists over the past decade. (See figure O-32.)

Figure O-32.
Portion of all journal publications¹ written with industry participation that are co-authored with universities



¹Includes the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information.

²See appendix table 5-27 for a description of the subfields included in these fields.

See appendix table 5-15 and p. 96 Science & Engineering Indicators — 1987

PUBLIC ATTITUDES TOWARD SCIENCE AND TECHNOLOGY

In 1981, the first major international comparative study of public attitudes towards science and technology was conducted. The study's results, which have recently become available, show that by a significant margin, the U.S. public held the most optimistic view of the long-run contributions of science to society. (See figure O-33.)

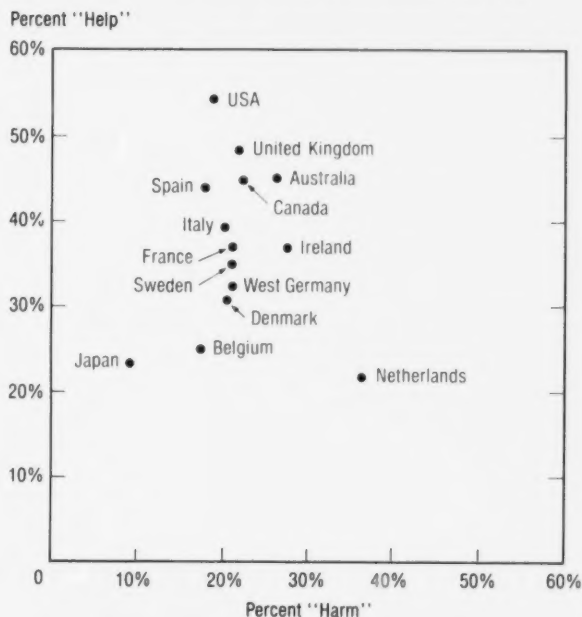
Allowing for inevitable sampling and translation variations in the national surveys, the data show that the English-speaking countries—headed by the U.S.—tend to be more sanguine about science (between two-fifths to more than one-half are positive) than are the continental European countries, which range around one-third positive. The exceptional positions of Japan and The Netherlands remain unexplained at this point.

The data also show that Western democracies closely resemble each other in the proportion of their populations which believes that in the long run, science is harmful to mankind—around 20 percent.

Historical experience from U.S. surveys shows that very general attitudes such as the one displayed here do not change very quickly over time. As comparative studies in this field develop, they can be expected to reveal interesting and important relationships between national public attitudes and public policies toward S/T.

Figure O-33.

Public perceptions of benefits and harms from scientific advance in selected countries: 1981-83



Note: Responses to the question "In the long run, do you think the scientific advances we are making will help or harm mankind?"

See appendix table 8-9 and p. 148.

Science & Engineering Indicators — 1987

Chapter 1

Precollege Science and Mathematics Education

Precollege Science and Mathematics Education

HIGHLIGHTS

- *Movements for educational reform are abundant.* Each of 50 State Governments has launched measures aimed at improving teacher supply or quality, enhancing course-taking in science and mathematics, or other similar policies to upgrade student performance. (See pp. 29-32.)
- *The problem solving ability of elementary and secondary students in science and mathematics remains at low levels.* Scores on the latest national assessment of mathematics show that students' problem solving/reasoning ability has declined, while their ability to solve problems requiring routine computation and rote memory has increased. (See p. 21.)
- *Although blacks and Hispanics scored well below their white counterparts in all assessments and in all age groups, the most pervasive gains were by black students.* By 1987, black 13-year-olds surpassed Hispanics in mathematics achievement. (See p. 21.)
- *American students perform relatively poorly in international assessments of science and mathematics.* Even our best mathematics students have the lowest achievement scores of any country for which comparable data are available. (See p. 24.)
- *It is doubtful if there is an adequate supply of teachers.* The grandchildren of the post-war "baby boom" are now entering school and, as a result, enrollment in elementary school is on the upswing. Teacher supply is down, especially among young college-educated women and minorities, and many teachers are approaching retirement age. (See pp. 27-29.)
- *Teacher preparation and qualifications reveal serious inadequacies.* Only one in three elementary science teachers has had a college chemistry course and only one in five a college physics course. (See pp. 25-27.)
- *More than one-half of all secondary school science teachers has never had a college course in computer science and almost one-half has had no college calculus.* (See pp. 25-27.)
- *Gender and race continue to be negatively correlated with school performance in science and mathematics.* Girls generally take less course work in mathematics and physical science than boys, although they equal boys in time spent in classroom biology. Enrollment of minorities (except for Asians) is much lower in science and mathematics than enrollment of whites. (See pp. 21-24.)

Throughout our Nation's history, we have placed a high priority on establishing educational policies to ensure an informed and educated citizenry. For example, the importance of advanced technical education to the economy was recognized more than 100 years ago with the enactment of the Land Grant College system.

After the Second World War, the new U.S. role in international defense placed additional strong demands on science and engineering (S E) education. Further spurred by the Soviet launch of Sputnik, the Federal Government helped stimulate the expansion of the S E workforce by supporting academic S E education.

More recently, policymakers have become concerned regarding America's competitive position in the world economy. It is becoming increasingly evident that strength in science and technology is a precondition for economic competitiveness. Consequently, there is a national need for careful nurturing of scientific, mathematical, and engineering education at all levels.

Since the early 1980's, copious national reports have been released on various aspects of education in the U.S. Most have concluded that there are serious problems in our precollege science and mathematics education.

Among the most prominent problems identified in these reports are:

- Academic performance is inadequate.
 - There is great disparity in achievement among ethnic groups and between boys and girls; and
 - U.S. high school students overall are less skilled in science and mathematics than some of our international competitors, especially the Japanese.
- The teaching force is inadequate.
 - The proportion of noncertified teachers in certain fields of science and mathematics is relatively high; and
 - The supply of new science and mathematics teachers has diminished and the number of graduates entering the teaching profession has also declined.
- The curriculum is inadequate.
 - Many students are "turned off" because of the routine nature of the subject matter; and
 - Rote skills rather than "higher order" analytic skills are taught.

Each of these problems is examined in the following sections of this chapter.

STUDENT ACHIEVEMENT AND PARTICIPATION

In the 1985/6 academic year, the National Assessment of Educational Progress (NAEP) again tested national samples of 9-, 13-, and 17-year-olds in mathematics, science, and—for the first time—computer competence. These test results permitted examination of trends in mathematics since the 1977/8 academic year¹ and trends in science scores since 1976/7.

Mathematics Achievement

Overall, there have been no statistically significant trends in the mathematics scores for the total sample since 1978. There have, however, been some significant changes from one assessment to the next, especially when subpopulations are examined. For example, the trend for the 13-year-olds turned downward in the most recent assessment (see figure O-16 in Overview), and that for male 9-year-olds swung upwards. (See appendix table 1-1.)

The most pervasive gains in mathematics achievement were displayed by black students, who gained—without exception—from 1978 to 1986. The 13-year-old blacks increased from 48 percent correct to 57 percent correct and in so doing surpassed the Hispanics in 1985/6. The 13-year-old Hispanics dropped significantly in the latest period, perhaps because of a substantial increase in their number and—with the increase—a likely increase in the number whose best language is other than English.

Analysis of subgroups of the mathematics items shows that those items designed to measure higher-level applications (problem solving/reasoning), routine applications, and understanding/comprehension tended to display downward trends; on the other hand, items reflecting skill (routine manipulation) and knowledge (mostly memory) and items measuring skill in using a calculator tended to display upward trends. These results suggest that teachers have responded to the demand for better performance by requiring more practice on routine computations and rote memory.

Biographical information provided by NAEP subjects indicates that the precollege student population changed from 1982 to 1986 in many ways, some of which may have had important implications for math and science education. At all three age levels, a smaller proportion of the sample subjects reported that their parents had only a high school education and a larger proportion reported they were college graduates. The 17-year-olds reported an increase in television watching (the 9- and 13-year-olds were not asked). The number watching TV 3 or more hours a day increased from 27 percent in 1978 to 36 percent in 1982 and 56 percent in 1986. This increase may have impaired achievement: "hours of watching" is negatively correlated with achievement. However, "time spent on homework" also increased; the percentage reporting 1 or more hours increased from 29 percent to 37

percent to 66 percent. This increase in homework may have counteracted the negative effect of television watching. Perhaps of more importance as far as the math achievement of 17-year-olds is concerned, the 1985/6 subjects reported a small increase in enrollments in intermediate and advanced mathematics (from 57 percent to 61 percent in geometry, algebra II, and calculus) and a small decline in the percentage who reached only pre-algebra or algebra I (from 40 percent to 37 percent). The increased mathematics enrollments coincided with the increase in achievement for 17-year-olds.

Changes in enrollment were especially evident for black students, whose enrollment in pre-algebra and algebra I increased slightly from 1978 to 1982 (50 percent to 54 percent) and then fell from 1982 to 1986 (54 percent to 45 percent). Further, the percentage reaching geometry, algebra II, or calculus dropped slightly in the first period (from 42 percent to 41 percent) and then increased substantially in the second (from 41 percent to 48 percent). These overall gains in mathematics enrollments may well explain gains in achievement by blacks.

Science Achievement

The national results for science achievement in general parallel those of mathematics except that the 13-year-olds did not display a downswing from 1982 to 1986. (See figure O-17 in Overview and appendix table 1-2.) Both males and females gained; as in former assessments, the females had higher means at 9 years (with the exception of 1976/7) and the males had higher means at the 13- and 17-year levels.² The difference between males and females converged slightly from 1982 to 1986 (by 0.3 percentage points for the 13-year-olds and 0.6 percentage points for the 17-year-olds).

White, black, and Hispanic students each gained except for 13-year-old Hispanics who declined slightly in science achievement from 1982 to 1986. Both blacks and Hispanics continued to perform appreciably less well than whites although the gap between blacks and whites decreased slightly, by 2 percentage points at each age level.

Computer Competence

In a new effort, the computer competence of 9-, 13-, and 17-year-olds was assessed in 1986. Computer competence was defined as general knowledge of computers and understanding of the concepts behind computer operation, familiarity with computer applications, and programming ability. The NAEP staff concluded that overall computer competence in primary and secondary schools was "markedly lower than expected or desired," that "students with the greatest proficiency are those who have most exposure to computers at home and at school," and that students who come from families with

¹Although a national assessment of science was conducted in 1969/70 and in mathematics in 1972/3, for technical reasons these results are not comparable with data for later years.

²Nine-year-olds were not tested for science content in the 1982 survey. The data for 1982 shown here are based on achievement of 9-year-olds on inquiry and science-technology and society items in 1982, weighted in proportion to the number of items on each scale, as a proxy for what achievement on content items might have been.

"high socioeconomic status are also among the best achievers." At all levels, males had somewhat higher scores than did females; white students outperformed both black and Hispanic students.

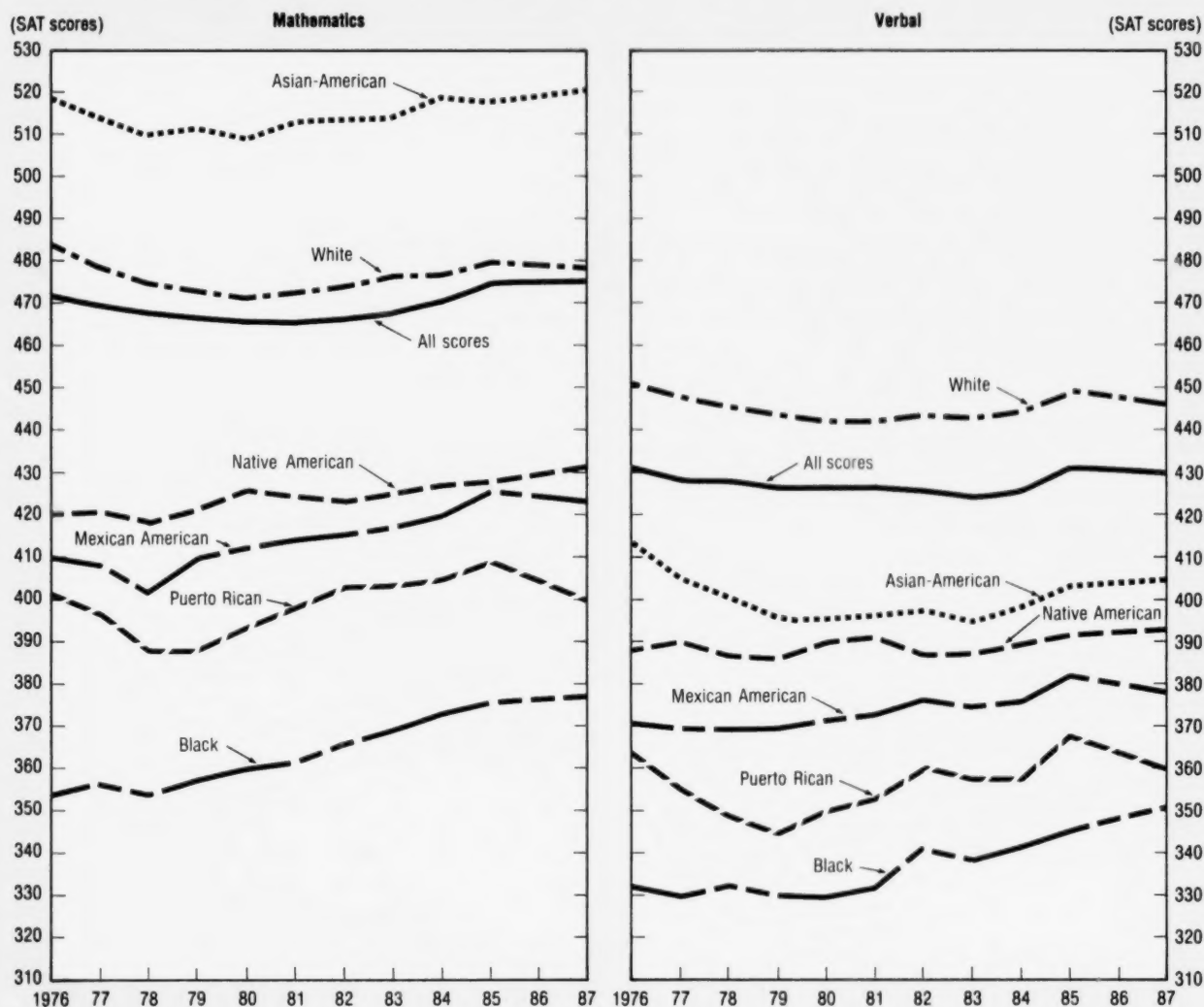
Students Intending to Major in S/E Subjects

Students who intend to major in science or engineering generally score much higher on Scholastic Aptitude Tests (SAT's)—both on the math and verbal portions—than do all students taking these tests. During 1975-86, however, SAT scores for students planning an S/E major declined. (See appendix tables 1-3 and 1-4.) This approx-

imately paralleled the declines for the total SAT population. Mean SAT quantitative scores for students intending to major in S/E disciplines declined from 520 in 1975 to 507 in 1981, then rose to 513 in 1986. SAT verbal scores for the same group were 464 in 1975, 444 in 1983, and 450 in 1986. As was the case in NAEP studies, males scored higher than females: in 1986, white males scored 546 on the SAT quantitative test compared with 496 for white females. Black males averaged 417 compared with 382 for black females.

For students intending to major in science and engineering, the highest SAT quantitative scores were for students intending to major in physical sciences (598),

Figure 1-1.
Average SAT scores for college-bound seniors, by ethnic group



See appendix table 1-5.

Science & Engineering Indicators — 1987

followed by mathematics and statistics majors (593). Similarly, students intending to major in physical sciences scored highest (526) on the SAT verbal test.

College-Bound Seniors

Although most minority groups traditionally score much lower than do whites, the verbal and quantitative SAT score averages of college-bound minorities have risen since the late 1970's, especially for black, Mexican-American, and Puerto Rican students. Moreover, Asian-American students score higher than do whites on the SAT quantitative test; while this is not paralleled by their SAT verbal results, Asian-Americans do score higher on the verbal test than do the other three minority groups. (See figure 1-1.)

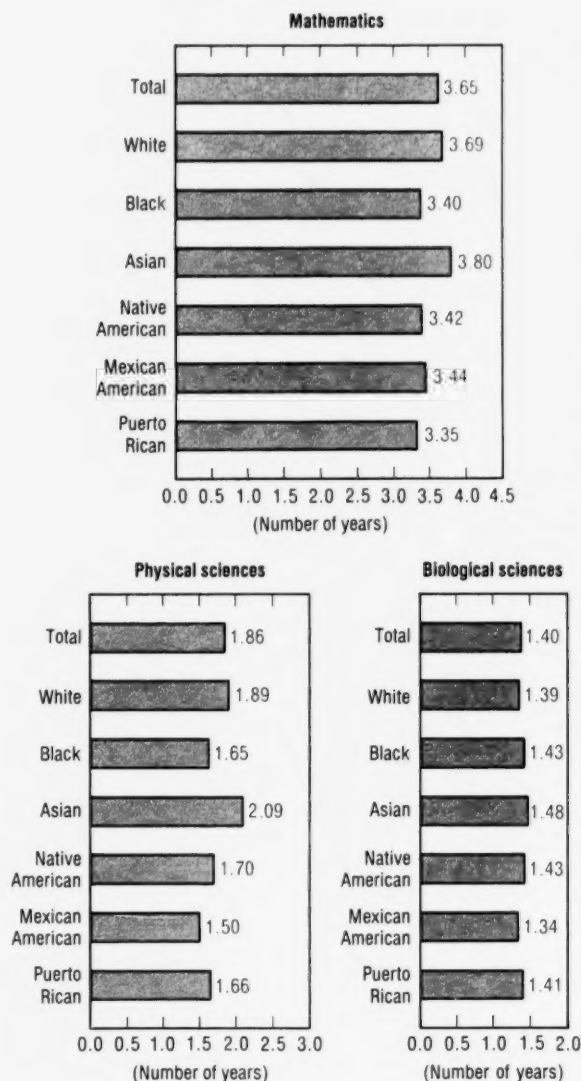
The chief reason most minority groups score relatively low on the SAT quantitative tests is that enrollment in high school mathematics courses varies considerably by ethnic group, with that of Asian students being significantly higher than enrollment by other minority groups. (See figure 1-2.)

Several explanations for the Asian-American performance pattern have been suggested, including the fact that most foreign-born Asian-Americans in S/E occupations come from the more affluent classes in their countries and may have experienced more favorable educational and social opportunities than their American-born counterparts. Additional suggested explanations include cultural differences in the Asian-American home, an English language difficulty which leads students to seek academic fulfillment in subjects based on the universal language of mathematics, and positive role models in the Asian-American community.¹ It has been noted too that Asian-American mothers have an unusually high level of education. Finally, it has also been suggested that relatively high quantitative ability differs by generation after immigration to the U.S., since American-born Asian-Americans of second, third, and fourth generations are underrepresented in S/E.¹

Math disadvantage for black students begins in elementary school and continues into high school where students select courses in one of three basic curricula: academic, general, and vocational.⁵ White students are overrepresented in the academic curriculum, while black and Hispanic students are overrepresented in both the general and vocational curricula, which require only lower-level mathematics classes. Even in the academic curriculum, however, where students are likely to enroll in advanced mathematics courses, 79 percent of the white high school students participated in advanced mathematics courses in 1982 compared to only 55 percent and 54 percent, respectively, of the black and Hispanic students.⁶

College-bound men and women differ in SAT verbal test scores only by about 12 points. (See figure 1-3.) There

Figure 1-2.
Average number of years of study
for college-bound students,
by ethnic group: 1984



SOURCE: Betty M. Vetter, "Attitudes, Participation and Achievement of Women and Minorities in Precollege Science and Math Education," unpublished report to the National Science Foundation (May 1986)

Science & Engineering Indicators — 1987

is, however, a 47-point difference between women's and men's SAT quantitative scores, a difference which has existed for at least 15 years. While this wide gap does not seem attributable only to the relatively small difference in mathematics course enrollment (see figure 1-4), no other satisfactory explanation has yet been advanced. Girls do take less course work in mathematics and physical sciences, but they slightly surpass boys in the amount of time spent in biology classes.

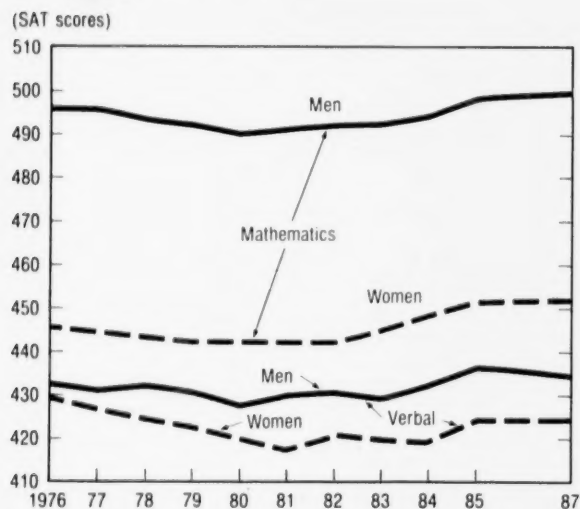
¹Vetter (1986), p. 16.

⁵Statements by Dr. Robert Suzuki before the U.S. Congress, House Committee on Science and Technology, U.S. Congress (1982), p. 12.

⁶Davis (1986), pp. 26-30.

⁷Ibid., p. 26.

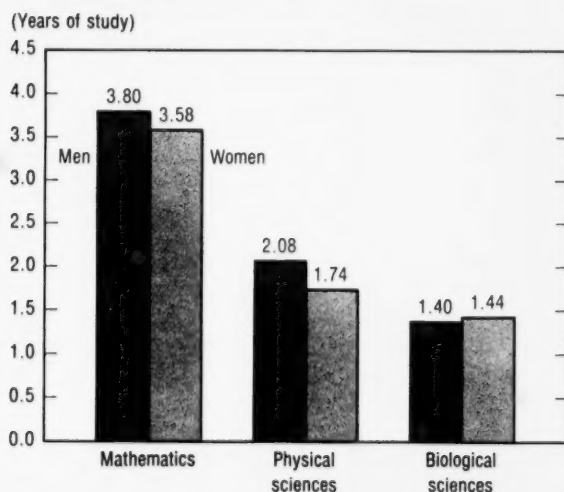
Figure 1-3.
Average SAT scores for college-bound seniors,
by gender



See appendix table 1-5.

Science & Engineering Indicators — 1987

Figure 1-4.
Average number of years of study for college-bound
students by gender: 1985



SOURCE: Betty M. Vetter, "Attitudes, Participation and Achievement of Women and Minorities in Precollege Science and Math Education," unpublished report to the National Science Foundation (May 1986)

Science & Engineering Indicators — 1987

International Comparisons of Achievement Test Results

U.S. students do not do well on science and mathematics achievement tests when compared with other countries studied. For example, an international survey conducted in 1981-82 compared the achievement in functions and calculus of the top 1 percent and 5 percent of 12th-grade college preparatory mathematics students in 13 countries. (See figure O-15 in Overview and appendix table 1-6.) The most able Japanese mathematics students attained higher scores than their counterparts in other countries in both subjects. Perhaps more significantly, the average Japanese student achieved higher scores in functions and calculus than the top 5 percent of the U.S. students in college preparatory mathematics. Additionally, the most able (top 1 percent) U.S. students scored the lowest of all 13 countries in algebra and were among the lowest in calculus.⁷ The algebra achievement of the U.S. top 5 percent group was lower than that of any other country except Israel.

For students in the eighth grade, five content areas were tested: arithmetic, algebra, geometry, statistics, and measurement. The U.S. scored at or near the international average for three of these topics: arithmetic, algebra, and statistics. On the remaining two topics, the U.S. scores were among the lowest one-quarter of the countries.⁸

Top Mathematics Test Scorers

Of high school seniors who scored above the 90th percentile on the SAT quantitative examination in 1986, about 44 percent intend to study science or engineering in college. (See appendix table 1-7.) More than one-half of the males who score in the 90th percentile plan to study science or engineering (see figure 1-5), while only about one-third of the high-scoring females are interested in S/E as a college major.

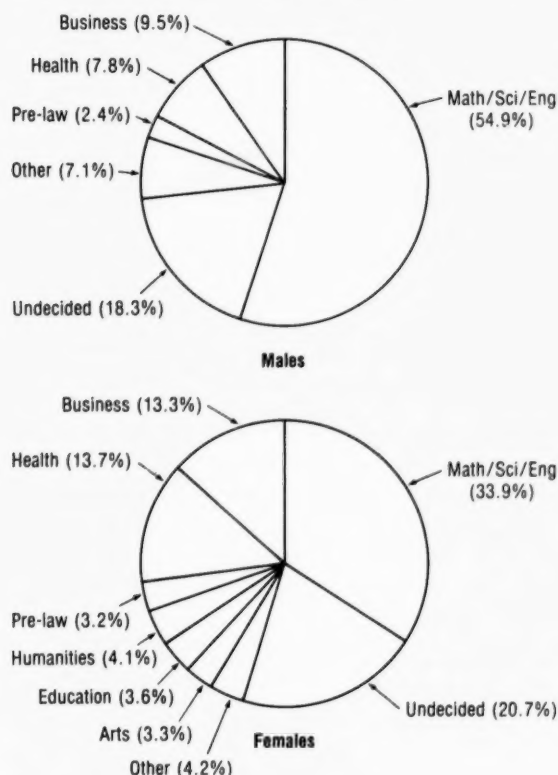
Over the last decade, top test scorers have exhibited an overall declining interest in majoring in mathematics and science and an increasing interest in an engineering major. (See figure 1-6.) Even though the percent of high-scoring students interested in a business major has increased between 1984-86 from 18 to 21 percent, this increase does not fully explain the declining interest in mathematics and science. Pre-med is also declining as are many smaller fields (not shown on the graph), such as other health fields and the humanities.

In the past few years, increasing numbers of examinees have indicated that they are undecided about their major field. There does not seem to be any one field drawing students away from mathematics and science, although undoubtedly business and engineering have attracted more high-scoring students in the past 2 years than they did previously.

⁷International Association for the Evaluation of Education Achievement (1987), p. 26.

⁸Ibid., p. 21.

Figure 1-5.
Major field selections of high school seniors scoring above the 90th percentile on SAT math



SOURCE: Jerilee Grandy, "Trends in Selection of Science, Mathematics, or Engineering as Major Fields of Study among Top-Scoring SAT Takers," unpublished report to the National Science Foundation, Educational Testing Service (March 30, 1987)

Science & Engineering Indicators — 1987

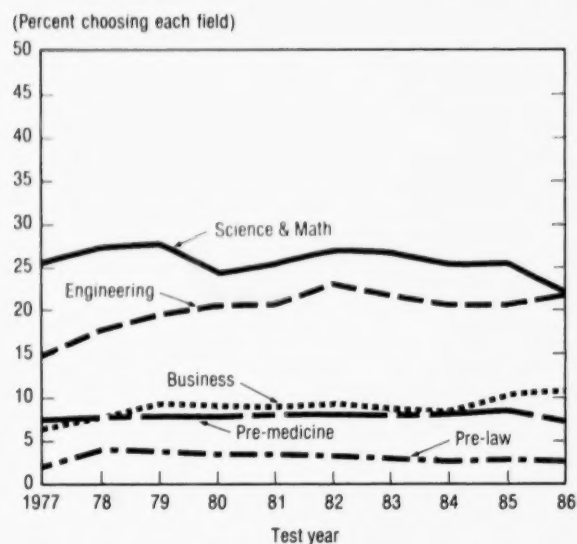
Trends over the past 10 years in the 90th percentile cutoffs look encouraging for the population as a whole and for each of the race/gender subgroups. (See appendix table 1-8.) SAT math scores for the top 10 percent rose from 623 to 642 in the last 5 years. The increase in minorities' scores is especially impressive. For instance, since 1979, the 90th percentile mathematics scores for both black males and females have increased 27 points.

Expected Majors of College Freshmen

A useful indicator of interest and secondary school participation in science and mathematics courses is the stated expected majors of freshman college students. These data are collected early in the freshman year, often during orientation programs, and therefore are likely to reflect precollege expectations and interests.

The percentages of women students who anticipate that they will choose a science, engineering, or mathe-

Figure 1-6.
Major field selections of examinees scoring above the 90th percentile on the SAT mathematics examination



See appendix table 1-7.

Science & Engineering Indicators — 1987

matics major have not changed substantively over the 1975-85 period, ranging from 18 to 20 percent. (See figure 1-7 and appendix table 1-9.) In contrast, men students have been reporting an increasing likelihood that they will opt for these majors—up from about 30 percent in 1975 to a high of 38 percent in 1983, but declining to 34 percent in 1985.

After a peak in 1977, there has been a long-term decline in the number of high school graduates. Therefore, the actual number of bachelor's degree students from whom graduate scientific and technical careers might be expected may also decline unless more interest can be generated among precollege students.

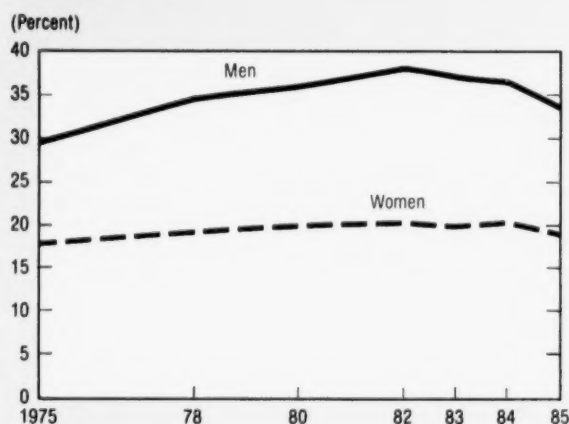
TEACHER CHARACTERISTICS

Characteristics of the Nation's precollege teaching force reveal several causes for concern. For example, teaching recruits historically have been drawn from among the least able college graduates. Furthermore, the standardized test scores of these teacher candidates declined throughout the 1970's.¹⁰ Although a number of academically talented people pursue careers in teaching and teacher education, these remain underrepresented in the field. As a result, teacher education tends to be relatively easy and nonchallenging.¹¹

¹⁰Sykes (1983). See also National Science Board (1986), p. 136.

¹¹Lanier (1984).

Figure 1-7.
Percent of freshmen at all U.S. institutions of higher education whose probable major field will be science or engineering



Note: "Science or engineering" includes only the following majors: biological sciences, engineering, mathematics, statistics, computer science, physical sciences, and the social sciences.

See appendix table 1-9.

Science & Engineering Indicators — 1987

In 1985-86, two national reports were issued focusing on the training and employment conditions of K-12 teachers. One of these studies, sponsored by the Carnegie Corporation,¹¹ targeted the enhancement of K-12 teaching as a profession. Recommendations included toughening certification standards, increasing salaries, and improving working conditions. Other recommendations were to develop "lead teachers," eliminate undergraduate programs in teacher education, develop new graduate-school programs leading to master's degrees in teaching, create a National Board for Professional Teaching Standards, restructure K-12 schools to allow teachers greater discretion in achieving State and local goals, increase teacher accountability for student performance, and increase efforts to recruit minority teachers.

A second report¹² (prepared by the so-called Holmes Group—the deans of schools of education at research universities) concentrated on teacher education. Some of its recommendations coincide with those made by the Carnegie study: increase teaching professionalism, increase salaries, abolish the undergraduate education degree, and place more emphasis on graduate education for prospective teachers.

As both studies indicate, the relatively low salary offered teachers creates a serious problem: it is, in fact, one of the primary reasons that the teaching profession at the precollege level has not been able to attract and retain more academically able professionals. Although teacher

salaries have begun to rise after a general decline during the 1970's, they typically have been lower than those for most other fields requiring a bachelor's degree. (See appendix table 1-10.)

An important shift recently has occurred in the social makeup of science and mathematics teachers. Traditionally, most elementary teachers have been female and the proportion of male teachers has increased with grade level. Since 1977, however, there has been an overall decrease in the proportion of male science and mathematics teachers. For instance, in 1977, more than two-thirds of mathematics teachers in grades 10-12 were male; in 1985/6, this proportion fell to a little more than 50 percent. (See appendix table 1-11.) It is not yet clear what the implications of this shift will be on the quality of science and mathematics teaching and on opportunities for student "role modeling."

Teachers' racial and ethnic makeup may also be significant in providing role models for minority students. The proportion of minorities who taught science and mathematics in 1985/6 was generally low, particularly in middle school and senior high school. Specifically, only 1 percent of grade 10-12 science and mathematics teachers were Hispanic and from 3 to 6 percent were black. (See appendix table 1-12.)

Courses Taken by Science and Mathematics Teachers

A profession's quality can be indicated by comparing standards established by professional groups to credentials attained by practicing members of the profession. The National Science Teachers Association (NSTA) has recommended that elementary science teachers have at least one college course in the biological sciences, one course in the physical sciences, and one course in the earth/space sciences. About 33 percent of the K-3 science teachers and 40 percent of 4-6 teachers meet that standard.¹³ While about 85 percent of elementary school teachers have taken at least one college course in the biological sciences, only about one in three has had a chemistry course and only one in five has had a physics course. (See appendix table 1-13.)

NSTA also recommends that junior high school science teachers have at least 36 credit hours in science, and senior high school teachers have at least 50 credit hours. Assuming that each science course averages 3.5 credit hours, more than 65 percent of 7-9 science teachers and more than 80 percent of 10-12 science teachers meet or exceed that standard; 40 percent of 7-9 science teachers and almost 60 percent of 10-12 science teachers meet or exceed the 50 credit hour standard. (See figure 1-8.)

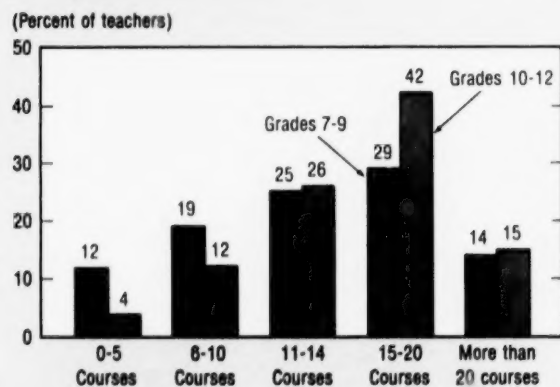
Nearly all of the 7-9 science teachers (97 percent) and the 10-12 teachers (93 percent) have taken a college course in biology. Almost one-half of 7-9 science teachers and two-thirds of 10-12 teachers have taken eight or more life science courses. (See appendix table 1-14.) Similarly, while large proportions of 7-9 science teachers (76 per-

¹¹Task Force on Teaching as a Profession (1986).

¹²National Commission for Excellence in Teacher Education (1985).

¹³Data in this subsection are from the 1985/6 National Survey of Science and Mathematics Education conducted for NSF by the Research Triangle Institute.

Figure 1-8.
Sciences courses completed by secondary
science teachers: 1985



Note: Since the highest number of courses a teacher could indicate for each of the 4 categories — life science, chemistry, physical/science, and earth/earth science — was "more than 6," these figures underestimate the totals for any teachers who completed more than 6 courses in a particular category.

SOURCE: Research Triangle Institute, 1985 National Survey of Science and Mathematics Graduation

Science & Engineering Indicators — 1987

cent) and 10-12 teachers (73 percent) have had at least one college-level course in the earth/space sciences, only 12 percent of the former and 6 percent of the latter have had eight or more courses in these areas. More than one-half of all secondary science teachers have never had a college course in computer science; almost one-half have had no college calculus.

In most of the fields of science and mathematics, sizable proportions of the teachers have taken one or more courses in specialized subfields over and above the general introductory course in the field. (See appendix table 1-15.) The exception is physics, where substantially fewer teachers have been exposed to specialized courses.

While 90 percent of K-6 mathematics teachers have had a mathematics course specifically for elementary school teachers, only 20 percent have had a course in geometry for teachers, 25 percent a course in probability and statistics, and 10 percent a college calculus course. (See appendix table 1-16.)

The National Council of Teachers of Mathematics (NCTM) recommends that junior high school mathematics teachers complete one calculus course, one computer science course, and one or more courses in teaching mathematics. Sixty-nine percent of grade 7-9 mathematics teachers meet or exceed the calculus recommendation, 60 percent have had a course in computer science, and 84 percent have had one or more courses in methods of teaching mathematics. (See appendix table 1-17.) At the 10-12 level, two-thirds (66 percent) of the teachers have had at least three calculus courses as suggested by NCTM, three-fourths have had a college course in computer science, but only 55 percent have had two or more courses on teaching methods. While two-thirds of 7-9

mathematics teachers and four-fifths of 10-12 teachers have had a college-level geometry course, and nearly an equal proportion have had a course in probability and statistics, fewer than 40 percent of each group has had a course in the applications of mathematics and only about one-third has had a course in the history of mathematics.¹⁴

Teachers' Perceptions of Their Qualifications to Teach

Elementary school teachers feel less well qualified to teach science than any other subject. This perception remained about the same between 1977 and 1985/6. In 1977, most elementary teachers indicated that they felt very well qualified to teach reading (63 percent); corresponding figures were 49 percent for mathematics, 39 percent for social sciences, but only 22 percent for science. (See table 1-1.) By 1985/6, teachers' confidence in their ability to teach mathematics, social studies, and reading had increased, but remained at about the same low level for the sciences. Science subjects were the only ones in which more than 4 percent of the teachers surveyed indicated that they felt "not very well qualified." When asked to name a specific science topic that they would find difficult to teach, teachers most commonly listed physics, chemistry, and—to a lesser extent—earth/space sciences topics.

At the secondary level, 13 percent of all science teachers felt in 1977 that they were inadequately qualified to teach science. By 1985/6, only 7 percent of secondary science teachers felt inadequately qualified. (See appendix table 1-18.)

One way to help remedy these feelings of inadequacy—and help teachers keep up with changes in their fields—is to provide opportunities for continuing (in-service) education. The survey data show, however, that between one- and two-fifths (depending on the grade level they teach) of science and mathematics teachers have not taken a course for college credit in their subject for the last 10 years. Moreover, while many teachers have participated in professional meetings, workshops, and conferences related to science or mathematics teaching, the amount of time devoted to in-service education activities was typically less than 6 hours during the year prior to the survey. (See appendix tables 1-19 and 1-20.)

TEACHER SUPPLY AND QUALIFICATIONS

A recent survey of teacher placement officers reported that, in the fields of math, physics, chemistry, bilingual education, multiply handicapped, and mental retardation, there is now a considerable shortage of teachers.¹⁵ Will there, then, be enough qualified candidates to meet the demand for classroom teachers in the future? (See figure 1-9.) With student enrollments projected to increase and retirements expected to accelerate, more teachers will be needed each year. This demand for new

¹⁴Research Triangle Institute (1986).

¹⁵Akin (1986).

Table 1-1. Elementary teachers' perceptions of their qualifications to teach various subjects: 1977 and 1985-86

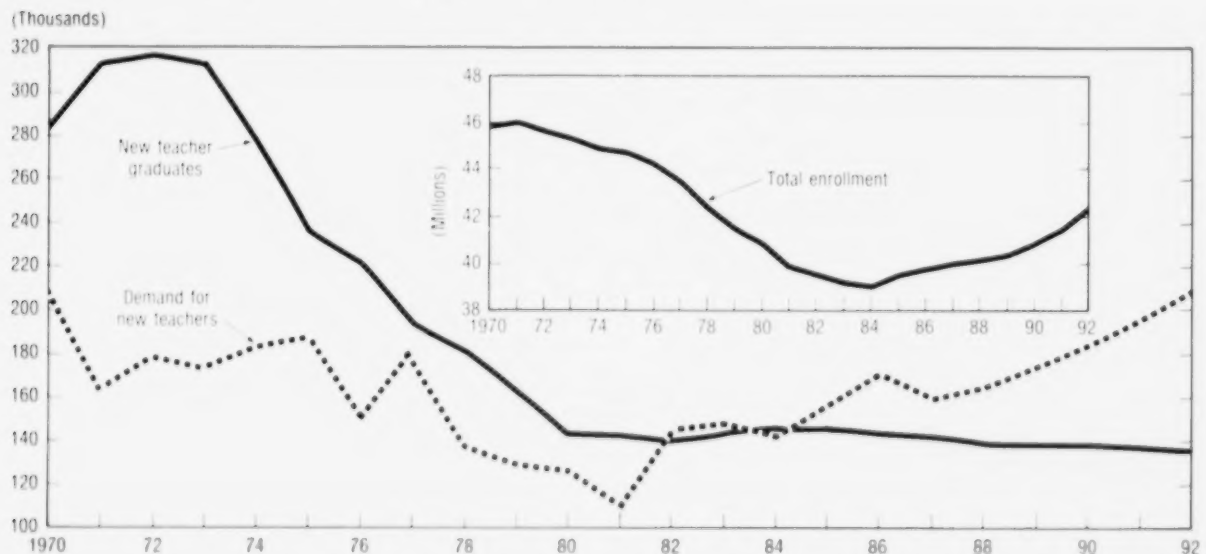
Subject	Percent perceiving that they are:			
	Not well qualified	Adequately qualified	Very well qualified	No answer
1977				
Mathematics	4	46	49	1
Social studies	6	54	39	1
Reading	3	32	63	2
Science	16	60	22	2
1985-86				
Mathematics	1	30	67	2
Social studies	4	47	47	2
Reading	1	15	82	2
Life science	11	60	27	2
Physical science	23	59	15	3
Earth space sciences	22	59	15	4

SOURCE: Research Triangle Institute. 1985 *National Survey of Science and Mathematics Education*

Science & Engineering Indicators—1987

Figure 1-9.

New hires in teaching^a and new teacher graduates,^b and total enrollment



^aData through 1983 are actual new hires. Data for 1984-93 are the intermediate value of three alternative projections.

^bData through 1984 are actual new hires. Data for 1985-93 are the intermediate value of three alternative projections.

Note: Data are for the school year beginning in the autumn of the given calendar year.

See appendix tables 1-21, 1-22, and 1-23.

Science & Engineering Indicators—1987

hiring will, because of enrollment increases, affect elementary and secondary levels at different times; elementary school teacher hiring is expected to increase from the mid-1980's into the early 1990's before declining. The demand for new hiring of secondary school teachers is expected to increase from the late 1980's into the early 1990's.

Recent reviews of mathematics and science teacher shortages conclude that misassignment is a major cause of the shortages of qualified teachers in these subject areas.¹⁰ Such misassignment occurs more frequently in

¹⁰Rumberger (1984).

physics and chemistry than in the biological sciences.¹⁷ According to NSTA estimates, approximately 30 percent of all secondary mathematics and science teachers are either "completely unqualified or severely under-qualified" to teach these subjects. Further, more than 40 percent of the total mathematics and science teaching force will retire by 1992.¹⁸ (See figure 1-10.)

Studies show that during the 1970's the proportion of women receiving bachelor's degrees in education decreased by one-half, while the proportion of degrees granted to women in the biological sciences, computer science, engineering, and law increased tenfold.¹⁹ Many of these women were among the most academically able and well-prepared members of the new bachelor recipients.²⁰ In addition to this loss of more academically trained teachers, current and impending teacher shortages may further detract from teaching quality. Given the projected high level of demand, two hiring patterns for mathematics and science teachers may become prevalent. First, there may be even more reassignment of less qualified teachers from other subject areas to mathematics and science courses. Although these individuals may be generally competent teachers, given the weakness and/or nonexistence of in-service retraining programs, mathematics and science teachers trained in their area of instruction would be preferable to those trained in other subject areas. Second, a full complement of new mathematics and science teachers may be hired. This might have other drawbacks since such new, inex-

perienced teachers may be less effective²¹ and may be more likely to leave teaching.²²

TEACHER REFORM MOVEMENTS

A recent national report about teaching as a profession stated that, "The 1980's will be remembered for two developments: the beginning of a sweeping reassessment of the basis of the Nation's economic strength and an outpouring of concern for the quality of American education."²³ This concern about the quantity and quality of teachers in K-12 education—especially in science and mathematics—has led both States and teacher education institutions to undertake a variety of corrective measures affecting how teachers are trained and certified, what they are paid, how their skills are maintained and enhanced, and the conditions under which they work. While relatively few of these initiatives are directed solely at science and mathematics teachers, the primary focus of concern is on this group of teachers. These initiatives are discussed below; it should be noted, however, that many of the reforms have only been undertaken in the last 4 years and their effectiveness cannot yet be fully gauged.

State Reforms

Between 1980 and 1984, all 50 States and the District of Columbia had launched at least one action to promote either the quantity or quality of elementary and secondary school teachers.²⁴ Altogether, 48 States have one or more initiatives designed to increase the supply of teachers; 44 States have at least one quality-related initiative.

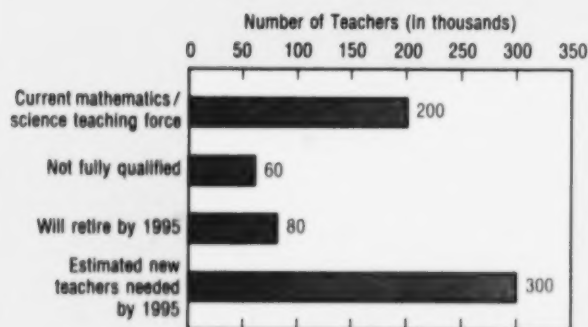
The most popular forms of State initiatives for increasing teacher supply are those designed either to lower the cost to the student of teacher training (38 States) or increase the benefits of being a teacher (38 States). Student costs are decreased primarily through loan forgiveness or other student financial programs. Teacher benefits are increased through raises, better working conditions, or greater social recognition. Twenty-six States have both lowered costs and increased benefits. (See figure 1-11.)

State initiatives designed to enhance teacher quality include: more provisions for further training of current teachers (28 States), higher admissions requirements for entry to teacher education programs (26 States), tougher teacher certification requirements (25 States), and performance evaluations of current teachers (25 States). (See figure 1-12.)

State teacher quantity initiatives have focused on potential or actual teacher pools, rather than on teacher training processes, because a major problem is lack of interest or incentive for individuals to enter the teaching profession. As a whole, the Nation has experienced declines in its teacher supply: it is anticipated that, in 1992, the supply of newly graduated teachers will fill only two-

Figure 1-10.

Status of the mathematics and science secondary-school teaching force



SOURCE: National Science Teachers Association survey in December 1982, reported in Hope Alrich, "Teacher Shortage: Likely to Get Worse Before It Gets Better," *Education Week* (July 27, 1983).
Science & Engineering Indicators — 1987

¹⁷Johnston and Aldridge (1984).

¹⁸Ibid.

¹⁹U.S. Department of Commerce, Bureau of the Census (1983 and 1973).

²⁰Vance and Schlechty (1982), pp. 22-27.

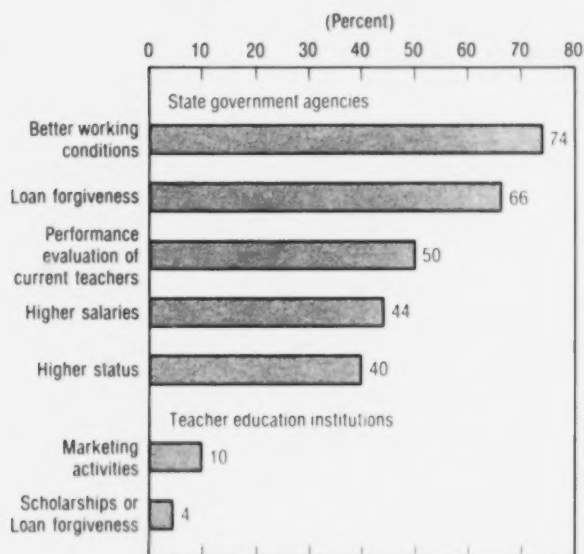
²¹Rosenholtz (1984), pp. 352-388.

²²Murnane (1985).

²³Task Force on Teaching as a Profession (1986), p. 11.

²⁴Education Commission of the States (1984).

Figure 1-11.
Percent of State government agencies and teacher education institutions which initiated policies and programs between 1980 and 1985 to enhance the number of teachers



SOURCE: Surveys conducted by the Education Commission of the States, Council on Education, reported in Paul T. Brinkman and Dennis P. Jones, "State and Institutional Initiatives to Increase the Quality and Quantity of K-12 Science and Mathematics Teachers," unpublished report to the National Science Foundation (June, 1986).

Science & Engineering Indicators — 1987

thirds of the available positions.²⁵ In addition, based on preliminary analyses, it appears that the attrition rate of chemistry, physics, and foreign language teachers is higher than that of other teaching fields; also, chemistry and physics teachers who leave the teaching profession are less likely to return to it.²⁶

Teacher quality initiatives can be grouped into three categories: those directed toward potential teachers, those involving certification of current teachers, and those aimed at the process of teacher education. Among the 44 States with recent quality-related initiatives, potential teachers are the target in 26 States, current teacher certification is the target in 35 States, and the training process is the target in 34 States. In 12 States, two of the three objectives have been targeted; in 20 States, all three objectives are receiving attention.

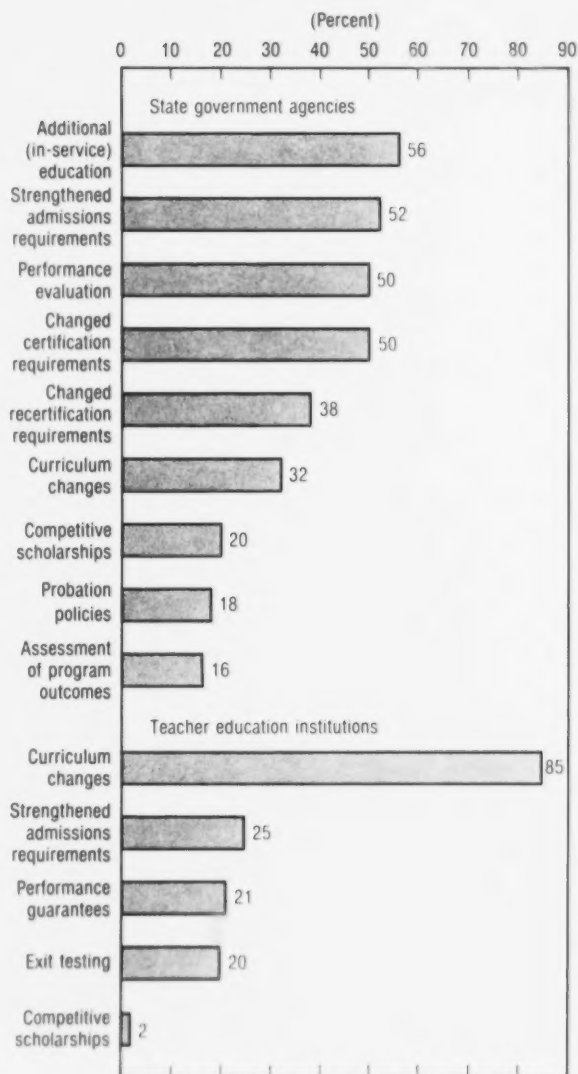
²⁵Darling-Hammond, et al. (1987), p. v.

²⁶Murnane and Olsen (1987).

Potential Teachers

The most frequent form of quality-related initiatives directed toward potential teachers is higher admissions requirements for entry into teacher education programs (26 States); competitive scholarship programs have been added in 10 States.

Figure 1-12.
Percent of State government and teacher education institutions which initiated policies and programs between 1980 and 1985 to enhance the quality of teachers



SOURCE: Surveys conducted by the Education Commission of the States, Council on Education, reported in Paul T. Brinkman and Dennis P. Jones, "State and Institutional Initiatives to Increase the Quality and Quantity of K-12 Science and Mathematics Teachers," unpublished report to the National Science Foundation (June, 1986).

Certification

New initiatives focusing on certification relate either to the certification of new teachers (25 States), or the recertification of current teachers (25 States). Competency testing—the main purpose of which is to screen out candidates deficient in basic skills and knowledge—is one approach to regulate entry into the teaching profession. As of 1986, 35 States had required competency testing as part of the process for initial teacher certification. (See appendix table 1-24.) Two States (Arkansas and Texas) had instituted testing for recertification of experienced teachers. In its recent report, the Carnegie Forum proposes a three-stage voluntary assessment process covering subject matter, education courses, and teacher performance—all under the aegis of a National Board for Professional Standards.

Teacher Education

Staff development of teachers is the most prevalent focal point of new State initiatives that attempt to enhance quality by changing the teacher training process. Some form of this type of initiative—such as providing funding, establishing training centers, or setting minimum standards for number of hours of training—has occurred in 28 States. Sixteen States have initiatives directed toward aspects of the training curriculum for new teachers; an additional eight states have taken steps to evaluate the outcomes of teacher education programs, primarily by comparative statistics on competency exam results. Nine States have initiatives designed to influence activities during a teacher's first years in the profession (sometimes referred to as an internship or probationary period).

Higher Education Reforms

Higher education institutions also have undertaken efforts aimed at reforming teacher quality/quantity. These have primarily involved efforts to attract students to teaching careers,²⁷ and include such marketing activities as visits to high schools and mailings of brochures (10 percent of the institutions) and additions of new scholarships or loan forgiveness programs (4 percent). (See figure 1-11.)

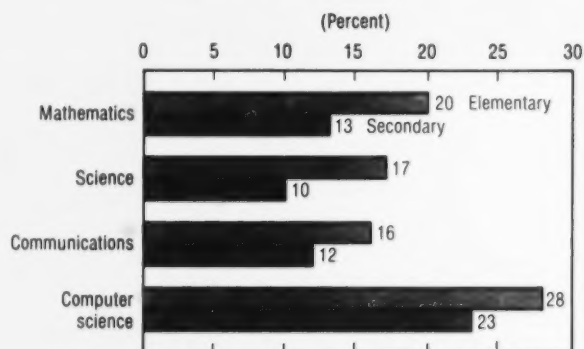
Another aspect of teacher education reform involves standardized tests for entry into teacher education, which have proliferated dramatically over the last 5 years.²⁸ At the beginning of the eighties, less than one-quarter of all institutions of higher education required these tests; by 1985, however, nearly one-half of them did. Public institutions are more likely than private ones to invoke entrance examination requirements. For elementary education programs, 54 percent of public institutions require entrance examinations, compared with 44 percent of private institutions; for secondary education programs, the figures are 52 percent and 44 percent, respectively.

²⁷Holmstrom (1985).

²⁸Brinkman and Jones (1986), p. 12.

To improve the quality of students majoring in education, some institutions have raised their required entry grade point average (GPA). By 1985, more than 100 institutions raised their GPA requirements from around 2.2 or 2.3 (on a 4-point scale) to a minimum of 2.5 to 2.9. Furthermore, a 1983 survey found that about 85 percent of teacher training programs have revised their curricula in the 5 years prior to the survey.²⁹ (See figure 1-12.) Another survey showed that since 1980, the average number of credit hours required in education courses had increased.³⁰ Another quality-related theme is to require less courses in education, and more in substantive subject matter areas. In elementary programs, the percentage of institutions increasing their requirements is highest for computer science (28 percent), mathematics (20 percent), science (17 percent), and communications (16 percent). Fewer institutions increased similar requirements for secondary programs. (See figure 1-13.)

Figure 1-13.
Percent of U.S. higher education institutions which increased their requirements for selected disciplines in elementary-school and secondary-school teacher education between 1980/81 and 1984/85



SOURCE: Surveys conducted by the Education Commission of the States, Council on Education, reported in Paul T. Brinkman and Dennis P. Jones, "State and Institutional Initiatives to Increase the Quality and Quantity of K-12 Science and Mathematics Teachers," unpublished report to the National Science Foundation (June, 1986).

Science & Engineering Indicators — 1987

Federal and Private Sector Programs

Other groups are also involved in efforts to improve the quantity and quality of K-12 teachers. These groups include teacher associations, local school districts, Federal agencies, and special commissions and task forces.

Teacher associations have worked to increase teacher benefits and to develop new means for quality control,

²⁹Ibid.

³⁰National Center for Education Statistics (1985).

such as a national certification standard. School districts directly influence the demand for teachers and can affect supply, usually by adjusting benefits or changing job requirements.

Federal agencies support various programs aimed at teacher preparation and enhancement. For example, in fiscal year 1987, the National Science Foundation (NSF) allocated nearly \$50 million to programs to improve science and mathematics teaching and learning. This funding provided support for developing new materials and model programs to improve undergraduate student teacher preparation and for effective continuing education for working teachers throughout their careers. NSF also supports seminars, conferences, research participation opportunities, and workshops to expand the scientific and mathematics knowledge base of teachers who will take local leadership roles in in-service training of their peers. Other NSF programs help local and regional communities provide both continuing education for teachers who lack the mathematics and science background for the courses they teach, and national recognition for distinguished science and mathematics teachers.¹¹

The Department of Energy, through its Lawrence Berkeley Laboratory (LBL), supports several programs to promote the benefits of direct association with science and technology to teachers and students in secondary education.¹² These programs include opportunities for student and teacher interaction in research conducted at LBL, and summer research positions for teachers at national laboratories.

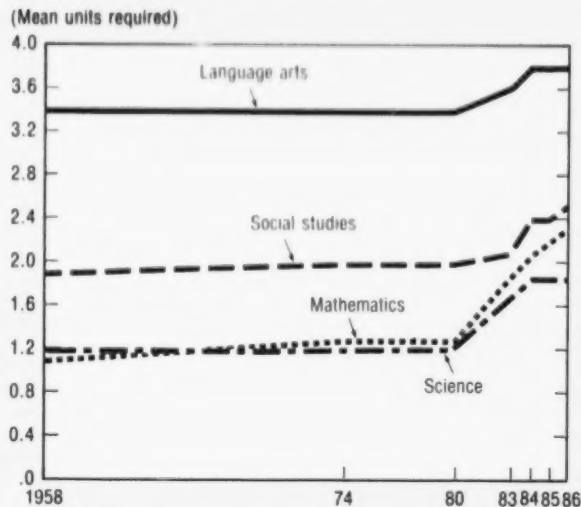
STUDENT REFORM MOVEMENTS

In 1985, 46 States required a minimum number of units for high school graduation. Of these, 39 States had increased their requirements between 1980 and 1985. After 20 years of stability, there have been sharp increases since 1980 in the number of 1-year courses ("Carnegie units") in mathematics and science required by States for high school graduation. (See figure 1-14.) For example, in 1958, 31 States required at least 1.1 year-long mathematics courses in order to graduate from high school; in 1986, 45 States required at least 2.3 units. (See appendix table 1-25.) Science requirements increased from 31 States requiring 1.2 units in 1958 to 45 States requiring 1.9 year-long courses in 1986. There were smaller increases in the requirements for social studies and language arts.

Twenty-two States now require that students pass a minimum competency test before awarding them a high school diploma. In some States, local schools have the option of setting their own standards for these tests, or—in certain cases where the State sets the standards—local schools have the option not to use examination results for grade promotion or graduation. (See appendix table 1-26.)

By 1985, 40 States had taken either legislative or State board action to require or permit schools to identify

Figure 1-14.
State-required Carnegie units¹ for high school graduation by subject



¹A Carnegie unit is a one-year course in the given subject.

See appendix table 1-25.

Science & Engineering Indicators — 1987

minimum basic skills that students should acquire. Policies differ widely concerning the grade levels and subjects involved.

RESEARCH ON TEACHERS AND TEACHING

A large volume of research evidence indicates that teachers play a highly significant role—far greater than those of selected committees, district supervisors, principals, or superintendents—in determining what takes place in the classroom. Not only do teachers make the ultimate decision about what they teach, they also rely heavily on the advice of other teachers as sources of information about new developments.¹³

Teachers also appear to be the primary decisionmakers in selecting and using curricular materials.¹⁴ While this does not mean that all teachers make the ultimate decision about the in-classroom materials (such decisions are often made by school or State board committees), most teachers do, however, have autonomy in the way they utilize these materials and teach their subject matter. This autonomy apparently encompasses teaching style, presentation mode, test selection, grade assignment, and—within the limits set by administrators—determining such activities as out-of-school field trips.

There is also evidence that teachers make a difference in what students learn in the classroom. This finding

¹¹NSF (1987).

¹²Otto (1986).

¹³Weiss (1978).

¹⁴Ibid.

comes from studies showing clearly that children who spend the year in different schools—and even in different classrooms within the same school—learn different amounts during the school year.³⁵ While these studies do not by themselves demonstrate that differences among teachers explain why more learning takes place in one classroom than another, it can be inferred that teachers are an important factor in explaining such differences.³⁶

Input-Output Studies

Another more challenging area of research tries to link teacher characteristics and student learning. Variables presumed to be indicative of teachers' competence—for instance, years of education, recentness of educational enrichment, years of teaching experience, academic ability, etc.—have been analyzed for their relevance to student learning. The results have been equivocal. Early studies of teachers' intelligence (usually measured by IQ) and its relation to student achievement have concluded that there is no such relationship.³⁷ The lack of effect of IQ could be because of negligible variability among teachers in this measure or because of IQ's tenuous relationship to actual performance.³⁸ Other studies have found that teachers' verbal ability is related to student achievement.³⁹ Verbal ability, rather than intelligence, may be a more sensitive measure of how well teachers can convey ideas and concepts.

Some studies have tried to relate the extent to which student achievement gains can be explained by teachers' demographic characteristics—e.g., teachers' education test scores and teaching experience. There are a few relatively consistent findings. For example, teachers with at least 3 to 5 years of experience are more effective on average than beginning teachers.⁴⁰ The dominant conclusion from such research, however, is that most variables used to depict teachers—gender, race, possession of a master's degree, undergraduate major in education—are not consistently related to teaching effectiveness as measured by student test score gains on standardized reading and mathematics achievement tests.⁴¹

Process-Product Studies

Another body of research has examined whether specific actions of teachers are systematically related to teaching effectiveness. These studies focus on whether student achievement in a specific subject is positively related to the amount of in-class time devoted to instruction in the subject, as well as how effectively class time is used. There is evidence, for example, that an increased exposure to mathematics may be particularly beneficial to

the lowest-achieving mathematics students.⁴² Elementary school teachers tend not to take many science and mathematics courses in college; this lack of interest/experience is reflected in classroom performance, where studies have shown that some second-grade teachers averaged only 15 minutes a day on mathematics instruction, while others spent up to 50 minutes a day.⁴³

A recent National Academy of Sciences report summarizes the current state of research on teachers and concludes that:

...neither input-output studies nor process-product studies provide sure guidance for the development of indicators of the quality of the mathematics and science instruction in school. In one sense this is discouraging, because it makes the task of developing reliable indicators of teaching effectiveness more difficult. In a different sense, however, the results are encouraging, because they underline the fact that effective teachers cannot be defined merely as individuals with specific demographic characteristics who have earned particular academic degrees, or as people who have been trained to behave in predictable routinized ways in the classroom. Such definitions obscure the characteristics that effective teachers have in common with the skills and attitudes of professionals.⁴⁴

ELEMENTARY AND SECONDARY MATHEMATICS CURRICULA

To understand and evaluate the tested mathematics achievement of U.S. students, the curricula they study—i.e., their opportunities to learn—must be examined. Substantial new findings on this aspect of education are available from the 1981-82 Second International Mathematics Study, covering schools in 20 countries around the world (only 15 countries participated in the eighth grade study). The study obtained detailed information on the content of intended mathematics curricula, what mathematics was actually taught, and how that mathematics was taught.⁴⁵ Achievement and attitudes were assessed using internationally developed tests and questionnaires. An important aspect of this study was obtaining reports from teachers as to whether the mathematics on test items had been taught during the year or prior to that year. The resulting data, called "opportunity to learn," provided useful information in interpreting achievement scores among countries.

Internationally, the opportunity-to-learn data correspond closely to the achievement data, as would be expected. For example, in Japan, opportunity-to-learn ratings are among the highest of any country; in the U.S.,

³⁵Hanushek (1972).

³⁶National Academy of Sciences.

³⁷Goar, et al. (1983), pp. 239-246.

³⁸Murnane (1985).

³⁹Summers and Wolfe (1975).

⁴⁰Penrick and Yager (1983), pp. 621-623.

⁴¹National Academy of Sciences.

⁴²Stallings (1976), pp. 43-47.

⁴³Galambos (1985).

⁴⁴National Academy of Sciences.

⁴⁵International Association for the Evaluation of Education Achievement (1987), p. 4.

on the other hand, these ratings are about at the international average, or in some cases lower. (See appendix tables 1-27, 1-28, 1-29, and 1-30.)

Eighth Grade

For comparative purposes, the following sections analyze the mathematics curriculum of the U.S. with Canada (British Columbia), which closely resembles the U.S. educational system, and Japan, whose students traditionally are among the highest scorers on international achievement tests. Thus, the profile of mathematics in the U.S. eighth grade curriculum resembles that of Canada quite closely, but differs markedly from that of Japan. Figure 1-15 shows that the U.S. and Canadian courses distribute their subtopics more evenly than do the Japanese, where most of the eighth grade concentration is on algebra and geometry. This may explain why the Japanese eighth graders performed so well, ranking first among the countries. (See table 1-2.)

In general, the test performances of U.S. students ranked in the bottom one-half of all 20 countries studied. As compared to a 1972 international assessment of eighth grade students, the 1981-82 results were very similar, with a slight improvement in arithmetic (up 6 percent) and a slight decline in geometry (down 6 percent).¹⁶ At

Table 1-2. Rank order of student achievements on eighth-grade¹ mathematics test for the United States, Japan, and Canada, by curricular subject: 1981/82

Subject	United States	Japan	Canada
Arithmetic	10	1	3
Algebra	12	1	7
Statistics	8	1	3
Measurement	18	1	8
Geometry	16	1	12

¹ Japanese students were tested in the seventh grade.

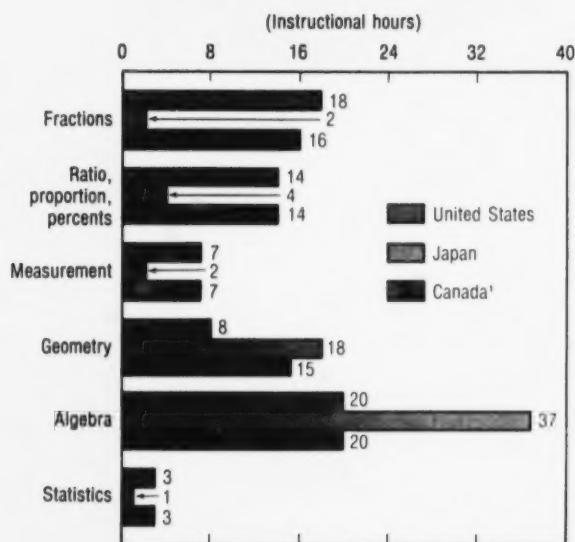
Note: The above rankings are based on the 20-country Second International Mathematics Study.

SOURCE: Travers, K.J., *Second Study of Mathematics, Detailed National Report—United States*, Stipes Publishing Company (December, 1986), pp. 167-68

Science & Engineering Indicators—1987

Figure 1-15.

Average instructional hours taught in eighth grade mathematics in the United States, Japan, and Canada, by topic: 1981/82



¹British Columbia

SOURCE: International Association for the Evaluation of Education Achievement, *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, National Report on the Second International Mathematics Study, University of Illinois (Stipes Publishing Company, January 1987)

Science & Engineering Indicators — 1987

the higher cognitive levels, 1981-82 students declined slightly as compared to 1972 students.¹⁷

It was found that the U.S. eighth grade mathematics curriculum is more like those at the end of elementary school (approximately sixth grade) elsewhere in the countries studied. But it should also be noted that the U.S. eighth grade mathematics curriculum varies more than is the case in other countries because of U.S. State and local control of schools.¹⁸

Among the factors identified as causes of deficiency in U.S. student achievement are: the amount of time allocated for instruction, size of classes, comprehensive nature of U.S. public schooling, preparation and status of teachers, and soundness of the teaching provided.¹⁹ However, U.S. analysts involved in the international assessment warn against singling out any one of these factors as "the villain." For example, the U.S. curriculum offers 141 hours of mathematics instruction per year—compared with 132 hours for Canada and 101 hours for Japan. Further, although Japanese students attend school 243 days per year—compared with 180 days in the U.S.—there was generally a lack of systematic relationship between length of school year in days and achievement among the 20 countries in the international assessment.²⁰

Twelfth Grade

The curricular patterns were more varied among the countries studied at the 12th grade level than at the 8th grade. While the U.S. curriculum was spread rather evenly across algebra, sets/functions, and complex numbers (offered for a total of 58 hours), the Japanese (with a total of 108 hours) have the greatest relative and absolute concentration on calculus. (See figure 1-16.) Japanese students receive twice as much calculus as U.S. students,

¹⁷Ibid., p. 161.

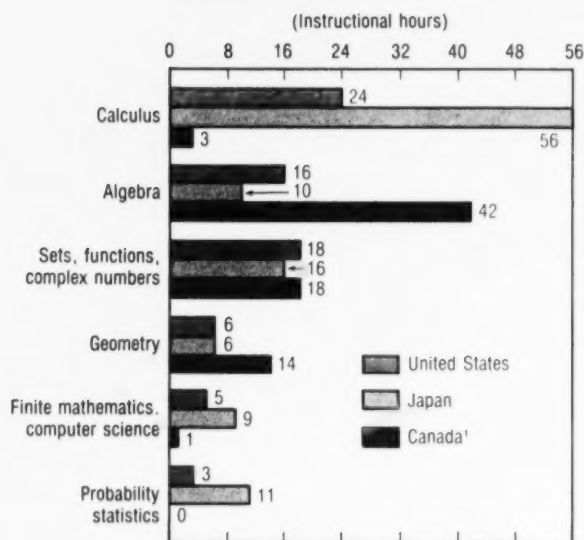
¹⁸Ibid., p. 159.

¹⁹Ibid., p. 51.

²⁰Ibid., p. 52.

¹⁶Travers (1986), pp. 163-167.

Figure 1-16.
Average instructional hours taught
in twelfth grade mathematics in the
United States, Japan, and Canada,
by topic: 1981/82



¹British Columbia

SOURCE: International Association for the Evaluation of Education Achievement, *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, National Report on the Second International Mathematics Study, University of Illinois (Stipes Publishing Company, January 1987)

Science & Engineering Indicators — 1987

and as much as U.S. students receive for all other sub-topics combined. The Canadian concentration is on algebra. Only one-fifth of the U.S. students taking these advanced courses receive Advanced Placement (AP) calculus whereas most of the Japanese students do. Thus, 4 to 5 times more Japanese than U.S. students take AP calculus.

With these considerations in mind, it is no surprise that Japanese 12th grade mathematics students do so well in comparison with those from the U.S. and Canada. (See table 1-3.) Japanese schools retain 92 percent of their 17-year-old students, compared to 82 percent for the United States and Canada, which further heightens these contrasts.⁵¹ It is interesting to note that Canada and the U.S. each outrank the other in performance in the two curricular areas to which they devote the greater number of hours of instruction.

Textbook Content

In addition to the opportunity-to-learn data, a recent study⁵² investigated how much of the content is "new" in

Table 1-3. Rank order of student achievements
on 12th-grade mathematics test for the
United States, Japan, and Canada,¹ by curricular
subject: 1981

Subject	United States	Japan	Canada
Sets and relations	10	2	14
Number systems	12	2	11
Geometry	12	2	14
Algebra	14	2	12
Probability and statistics	12	2	13
Elementary functions and calculus	12	2	15

¹ British Columbia.

Note: The above rankings are based on the 15-country Second International Mathematics Study.

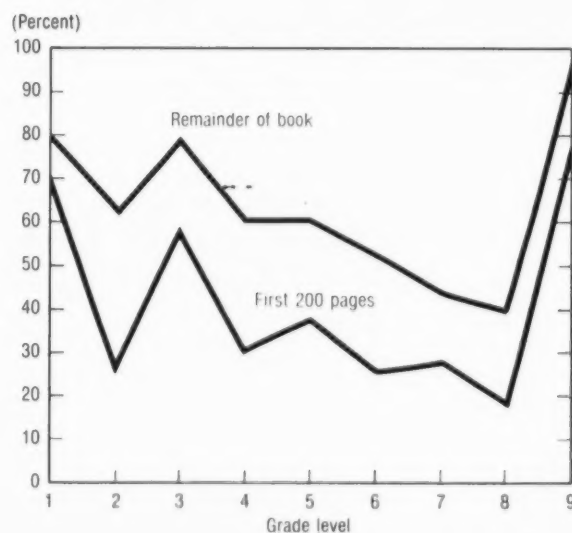
SOURCE: Travers, K.J., *Second Study of Mathematics, Detailed National Report — United States*, Stipes Publishing Company (December, 1986), pp. 359-362

Science & Engineering Indicators—1987

three K-8 mathematics textbook series and the algebra books published by the same companies. Content was defined as "new" in a cumulative sense—a topic was new in a fourth grade text, for example, if it had not appeared in any of the K-8 texts of the series. The study found that a generally low percentage of new content is clearly evident. (See figure 1-17.) First, there is a plunge in percentage of new content between first and second grade math

Figure 1-17.

Average percent new content in three mathematics text series, the first 200 pages and the remainder of the book



See appendix table 1-31

Science & Engineering Indicators — 1987

⁵¹Travers and Kifer (1986), p. 10.

⁵²Flanders (1986).

texts; the average percentage then declines rather steadily from fifth through eighth grade. Finally, there is a huge jump in the percentage of new content between eighth and ninth grade texts as algebra is introduced into the curriculum.

The study also analyzed the new pages of content when each book is split at page 200. For grades 1-3, this is about two-thirds of the way through the text; for grades 4-8, it is approximately the halfway point. For the algebra texts, it is again about two-thirds of the way through. The study found, as expected, that most new content in any mathematics text is concentrated after page 200. In grades 7-8, for example, less than 28 percent of the first half of the books contain new material.

In its conclusions, the study noted that the percent of new content is very low (49 percent or less) in all mathematics texts beyond the third grade; the seventh and eighth grade texts have the least (33 percent). This last ratio seems particularly low when compared with the approximately 90-percent new content of algebra books in the ninth grade. New content is covered primarily at the latter part of the school year; furthermore, not all teachers cover all chapters in the latter parts of the texts.

The authors summarize their findings as follows:

There should be little wonder why good students get bored—they do the same thing year after year. Average or slower students get the same message, and who could blame them for becoming complacent about their math studies? They know that if they don't learn it now it will be retaught next year. Then students encounter an algebra course. The pace picks up (there are about 100 more pages in an algebra book than an eighth grade text), the new content comes at them at an 88-percent level (over 4 days per week they face new content), and the old content is usually presented with a new degree of formalism that clouds the fact that it is just review.⁵³

Student Attitudes toward Mathematics

The attitudes of students toward mathematics determine in part their success in mathematics and their inter-

est in mathematically related careers. The attitudes of 12th graders in the Second International Mathematics Study were generally more favorable than those of the 8th graders. This may be because of greater familiarity with the subjects and the fact that by the 12th grade, a greater proportion of the more able students are taking mathematics. For example, 85 percent of the 12th grade mathematics students felt that the subject helps one think logically; this belief was shared by only 64 percent of the 8th graders. The older students were less likely to believe that there is always a rule to follow in mathematics—67 percent versus 82 percent. (See appendix table 1-32.)

Overall, the attitudes of U.S. students tended to be positive, contrasting sharply with those of the Japanese students who had rather negative attitudes toward the subject and found the mathematics class an unpleasant place to be.⁵⁴

Two-thirds of the eighth grade U.S. mathematics students thought the subject to be of high importance; 55 percent found it easy, but only 40 percent liked it. (See appendix table 1-33.) Very similar overall ratings were given by 12th graders to the importance, difficulty, and interest in mathematics. (See appendix table 1-34.) Further, attitudes toward curricular subtopics varied widely in both grade levels. The most liked item in both grade levels was "calculators." In both grades, there was strong evidence of a desire to do well in mathematics, that mathematics is generally learnable, and that assigning more mathematics would not be widely resisted. As would be expected for students who have elected to take advanced mathematics, 12th grade students were more positive. (See appendix table 1-32.)

There was little support for a view of mathematics as primarily a male subject or career opportunity. Less than 20 percent of the students at both levels believed that men make better scientists and engineers, or that boys need to know more mathematics than girls, or that boys have more natural ability in mathematics than do girls.⁵⁵

⁵³Ibid., p. 7.

⁵⁴Travers and Kifer (1986), p. 35.

⁵⁵Travers (1986), p. 387.

REFERENCES

Akin, J.N., *Tenth Annual Teacher Supply/Demand Report* (Madison, WI: Association for School, College and University Staffing, 1986).

Brinkman, P.T. and D. Jones, "State and Institutional Initiatives to Increase the Quantity and Quality of K-12 Science and Mathematics Teachers" (Boulder, CO: National Center for Higher Education Management Systems, 1986).

Darling-Hammond, L., A.E. Wise, and B. Berry, *Effective Teacher Selection from Recruitment to Retention* (Santa Monica, CA: Rand Corporation, 1987).

Davis, J., *The Effect of Mathematics Course Enrollment on Racial/Ethnic Differences in Secondary School Mathematics Achievement* (Educational Testing Service, 1986).

Education Commission of the States, *50-State Survey of State Incentives for Attracting Science and Mathematics Teachers* (Denver: 1984).

- Flanders, J., "How Much of the Content in Mathematics Textbooks is New?," unpublished paper, 1986.
- Galambos, E.C., *Teacher Preparation: The Anatomy of a College Degree* (Atlanta: Southern Regional Education Board, 1985).
- Hanushek, E., *Education and Race* (Lexington, MA: Heath-Lexington, 1972).
- Holmstrom, E.I., *Quality in Teacher Education Programs* (Washington, DC: American Council on Education, 1985).
- International Association for the Evaluation of Education Achievement, *The Underachieving Curriculum* (Champaign, IL: Stipes Publishing Co., 1987).
- Johnston, K.L. and B.G. Aldridge, "The Crisis in Science Education: What Is It? How Can We Respond?," *Journal of College Science Teaching* (September/October 1984).
- Lanier, J., "Research on Teacher Education," Occasional Paper No. 80 (Institute for Research on Teaching, Michigan State University, 1984).
- Murnane, R.J., "Do Effective Teachers Have Common Characteristics?: Interpreting the Quantitative Research Evidence," paper presented at the National Research Council Conference on Teacher Quality in Science and Mathematics, Washington, DC, June 1985.
- Murnane, R.J. and R.J. Olsen, "The Career Paths of Michigan School Teachers," paper presented to the American Educational Research Association, Washington, DC, April 1987.
- National Academy of Sciences, *Improved Indicators of Science and Mathematics Education in Grades 1-12*, unpublished document.
- National Center for Education Statistics, Planning Group on Teaching and Teachers, *New Initiatives: The Teaching and Teachers Program* (Washington, DC: Government Printing Office, 1985).
- National Center for Education Statistics, *The Condition of Education: 1987 Edition* (Washington, DC: Government Printing Office, 1987).
- National Commission for Excellence in Teacher Education, *Call for Change in Teacher Education* (Washington, DC: American Association of Colleges for Teacher Education, 1985).
- National Science Board, *Science Indicators—1985* (Washington, DC: Government Printing Office, 1986).
- National Science Foundation, *Teacher Preparation and Enhancement, Program Announcement and Guide*, NSF 87-10 (Washington, DC: NSF, 1987).
- Otto, R., "The Laboratory: A Link Between Research and Precollege Education," *LBL Research Review* (Summer 1986).
- Penrick, J.E. and R.E. Yager, "The Search for Excellence in Science Education," *Phi Delta Kappan*, 64(8) (1983).
- Research Triangle Institute, *Report of the 1985-86 National Survey of Science and Mathematics Education* (Research Triangle Park, NC: Research Triangle Institute, November 1986).
- Rosenholtz, S.J., "Effective Schools: Interpreting the Evidence," *American Journal of Education*, 93 (1984).
- Rumberger, R., "Is There Really a Shortage of Mathematics and Science Teachers: A Review of the Evidence," Report No. 84-A26 (Stanford, CA: Institute for Research on Educational Finance and Governance, Stanford University, 1984).
- Soar, R.S., D.M. Medley, and H. Coker, "Teacher Evaluation: A Critique of Currently Used Methods," *Phi Delta Kappan*, 65(4) (1983).
- Stallings, J., "How Instructional Processes Relate to Child Outcomes in a National Study of Follow Through," *Journal of Teacher Education*, 27 (1976).
- Summers, A.A. and B.L. Wolfe, *Equality of Educational Opportunity Quantified: A Production Function Approach* (Department of Research, Federal Reserve Bank of Philadelphia, 1975).
- Sykes, G., "Public Policy and the Problem of Teacher Quality: The Need for Screens and Magnets," in L.S. Shulman and G. Sykes (eds.), *Handbook of Teaching and Policy* (New York: Longman, Inc., 1983).
- Task Force on Teaching as a Profession, *A Nation Prepared: Teachers for the 21st Century* (New York: Carnegie Forum on Education and the Economy, 1986).
- Travers, K.J., *Second Study of Mathematics, Detailed National Report—United States* (Champaign, IL: Stipes Publishing Co., 1986).
- Travers, K.J. and E. Kifer, *Opportunities to Learn Mathematics in U.S. Classrooms*, unpublished report, 1986.
- U.S. Congress, House Committee on Science and Technology, Subcommittee on Science, "Symposium on Minorities and Women in Science and Technology," statements by Dr. Robert Suzuki (Washington, DC: Government Printing Office, 1982).
- U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1983 and 1973 Editions* (Washington, DC: Government Printing Office).
- Vance, V.S. and P.C. Schlechty, "The Distribution of Academic Ability in the Teaching Force: Policy Implications," *Phi Delta Kappan*, 64 (1982).
- Vetter, B.M., *Attitudes, Participation, and Achievement of Women and Minorities in Pre-college Science and Math Education*, unpublished document, 1986.
- Weiss, I.R., *Report of the 1977 National Survey of Science, Mathematics and Social Science Education* (Research Triangle Park, NC: Research Triangle Institute, 1978).
- Weiss, I.R., *Report of the 1985-86 National Survey of Science and Mathematics Education* (Research Triangle Park, NC: Research Triangle Institute, November 1987).

Chapter 2

Higher Education for Scientists and Engineers

Higher Education for Scientists and Engineers

HIGHLIGHTS

- *Full-time undergraduate engineering enrollments decreased from 406,000 to 370,000 between 1983 and 1986. In contrast, however, full-time graduate enrollments in engineering increased between 1983 and 1986 from 55,000 to 62,000. This increase is largely explained by the growth in foreign student enrollments. (See pp. 41-44.)*
- *Foreign graduate students represented 20 percent of all science and engineering (S/E) graduate students in 1986. They have increased their enrollments at an average annual rate of 6.9 percent since 1980, compared with a rate of 0.5 percent for U.S. citizens. (See p. 44.)*
- *Part-time enrollments in all graduate S/E programs increased by 3.7 percent from 1980 to 1986, compared with a growth in full-time enrollments of 1.9 percent. This difference is even greater in master's degree-granting institutions than in doctorate-granting schools. Full-time enrollment growth at master's-granting institutions between 1980 and 1986 was negligible, while part-time enrollments at these schools increased at an average annual rate of 5.6 percent. Thirty-one percent of graduate enrollments in master's degree-granting institutions were full-time in 1986, compared with 68 percent in doctorate-granting institutions. (See pp. 42-43.)*
- *Between 1984 and 1985, full-time enrollments of black U.S. citizens in graduate S/E programs declined 6 percent (from 7,632 to 7,272), and remained unchanged in 1986. Part-time enrollments of blacks decreased from 7,295 to 7,119 from 1985 to 1986. (See pp. 43-44.)*
- *S/E Ph.D.'s continue to increase but remain below the peak years of 1972 and 1973. These increases are wholly accounted for by foreign citizens. (See pp. 44-45.)*
- *Since 1983, about 25 percent of all S/E doctorates have been awarded to women. Women earned 38 percent of S/E baccalaureates and 30 percent of S/E master's degrees in 1985. These ratios are considerably higher than those of just 10 years ago. (See p. 45.)*
- *The employment of doctoral scientists and engineers in academia increased at 3 percent to 4 percent per year between 1977 and 1985. The employment of doctoral engineers increased at 4 percent per year; employment of doctoral scientists increased at 3 percent per year. (See pp. 48-49.)*
- *U.S. academic faculties continue to age except in engineering. In the sciences, the proportion of doctoral scientists younger than 40 years decreased from 33.8 percent to 32.2 percent from 1983 to 1985. By contrast, in engineering, the proportion of doctoral scientists younger than 40 increased between 1983 to 1985 from 28.2 percent to 29.8 percent. (See pp. 48-49.)*
- *Most S/E Ph.D.'s earned their baccalaureates at research-intensive and other doctorate-granting institutions. Proportions of S/E Ph.D.'s earning their baccalaureates at research-intensive universities have declined over the decades, reflecting the growth of comprehensive and other doctorate-granting schools. Baccalaureate origins differ by gender, racial/ethnic group, and field. In addition, a small number of selective small schools produce relatively large percentages of their baccalaureates who go on to obtain the Ph.D. (See pp. 47-48.)*

In the past few years, the Nation has become increasingly aware of the significance of an educated population—especially in science and engineering (S/E)—in influencing U.S. international economic competitiveness. This chapter therefore focuses on four major sets of indicators of higher education in science and engineering:

- U.S. enrollments in S/E higher education;
- S/E degrees awarded;
- Student support patterns; and
- Information on institutions and faculty in S/E higher education.

This chapter also discusses several other trends in S/E higher education of concern to policymakers. One of these is the decreasing size of the traditional college-going population in the United States. Other trends of interest include: the rates at which women choose to study science and engineering; participation in S/E higher education of underrepresented minority groups; the degree to which the U.S. higher educational system is becoming "internationalized" as it attracts increasing numbers of foreign students in S/E fields; and trends toward part-time study, often by older-than-average students, and in contrast to declines in the number of students pursuing full-time S/E studies.

The chapter also provides data on the undergraduate institutions of S/E Ph.D. earners.

ENROLLMENTS

This section presents indicators of S/E enrollments for both undergraduates and graduates, covering college enrollment rates of different population groups; recent trends in enrollment patterns which have helped offset declines in the normal college-age population; and important differences in S/E field enrollments which will influence the mix of degrees awarded to these students as they complete their studies and enter the job market or graduate schools.

Undergraduate Enrollments

Indicators of participation in undergraduate education are restricted to aggregate trends in college-going rates of various age, ethnic, and gender groups.¹ These gross indicators, when observed over time,² suggest the value placed on and access to higher education by these various groups and how these evaluations may be changing as shown by changing rates of college attendance.

Figure O-18 in the Overview shows the college-going rates for U.S. 18- to 21-year-olds. Throughout the 1970's and 1980's, about one-third of the total U.S. population in these age groups were enrolled in institutions of higher education. (See appendix table 2-1.) During the past 5 years, the college-going rates for some groups in the population have increased by 5 to 6 percentage points. These increases—especially those for women—have kept total undergraduate enrollments sufficiently high to compensate for the decline in size of the 18-year-old population, which began in 1979. According to the Census of Population, total college enrollments (all institutions, both genders, all races) have remained virtually unchanged for 3 years.

1985 Freshmen

Two specialized sources of indicators show the intentions of freshmen to major in certain fields. One of these sources is an annual survey of engineering and engineering technology programs conducted by the Engineering Manpower Commission of the American Association of Engineering Societies. The other is a national study of freshmen conducted each fall by the Cooperative Institutional Research Program at the University of California, Los Angeles (UCLA).

Engineering and Technology Enrollments. Each fall, the Engineering Manpower Commission surveys U.S. engineering and engineering technology programs to estimate program enrollments.³ These specialized data—while not strictly comparable to the other data in this chapter—are indicators of trends in undergraduate in-

tentions to obtain a degree in engineering, either at the bachelor's or 5-year level, or at the associate or 2-year level.⁴

Total full-time enrollments in engineering programs decreased between 1983 and 1986 at an average annual rate of -3.1 percent. (See table 2-1.) The overall pattern showed significant growth from 1979 to 1982, a leveling off in 1983, and declines in 1984, 1985, and 1986. Part-time enrollments, in contrast, continued to increase by an average of 2.9 percent per year since 1983. Part-time students constitute 9 percent of all enrollments.

Enrollments in engineering technology programs—which provide specialized skills for performing technical tasks at a sub-professional level—have increased for both full- and part-time students by an annual average of 7.6 percent from 1979 to 1985. However, all engineering technology enrollments declined from 1983 to 1985. A growing number of full-time engineering technology students continue past the associate degree level to work on their bachelor of engineering technology degree; these enrollments increased by an average annual rate of 14.5 percent between 1979 and 1985.

*Freshmen Characteristics.*⁵ The most recent survey of freshmen in institutions of all types shows that the 1986 freshmen expect to study longer and earn higher degrees than did freshmen 5 years previously. (See figure O-19 in Overview.) For example, freshmen who intend to obtain Ph.D.'s (in all fields) increased from 8.2 percent in 1982 to 9.7 percent in 1986; similar increases were reported in the relative percentages of entering freshmen hoping to attain bachelor's or master's degrees. (See table 2-2.)

Freshmen in 1986 were less likely to be planning a major in an S/E field than was the case in 1982. One of the more notable decreases was in the number of freshmen planning to major in computer science, down from 4.4 percent in 1982 to 1.9 percent in 1986. Engineering, too, decreased as a planned major, dropping from 12.6 percent in 1982 to 10.9 percent in 1986.

Indicators of these freshmen's career objectives also reflect these choices of major. The percent of entering freshmen planning careers as computer programmers or analysts dropped by more than one-half from 1982 to 1986. Engineering also declined for this period as a career of choice.

Graduate Enrollments

Total graduate student enrollment in science and engineering fields in all institutions increased at an average

¹A special survey of engineering and technology enrollments is discussed below.

²The Bureau of the Census' Current Population Survey (CPS) is conducted each October. CPS is a survey of approximately 60,000 households, covering about 125,000 people and 8,000 college students. Because the data discussed here are developed from a sample of the population, data on smaller groups of the population should be used with care.

³Engineering Manpower Commission (1986).

⁴The data on engineering programs are from 4- and 5-year programs approved by the Accreditation Board of Engineering and Technology. Upon successful completion of these programs, the student receives a bachelor of engineering degree or, in the case of the 5-year programs, an "engineering professional degree." The engineering technology enrollments, in contrast, are usually 2-year programs terminating in an associate degree, but some of these programs also include 4-year study.

⁵All of the data discussed in this section are from *The American Freshman: National Norms For Fall 1982, 1983, 1984, 1985, and 1986* by the Cooperative Institutional Research Program, UCLA. Excluded from the survey are part-time freshmen and students who have previously attended college for credit. Also excluded are semi-professional and proprietary schools, as well as some very small schools. For a complete description of survey methodology, see any of the UCLA volumes.

Table 2-1. Undergraduate enrollment in engineering and engineering technology programs

	1979	1980	1981	1982	1983	1984	1985	1986 ¹
Engineering programs								
Total full-time	340,488	365,117	387,577	403,390	406,144	394,635	384,191	369,520
Freshmen	103,724	110,149	115,280	115,303	109,638	105,249	103,225	99,238
Sophomore	78,594	84,982	87,519	89,785	89,515	83,946	79,627	76,195
Junior	74,928	80,024	86,633	90,541	91,233	89,509	84,875	80,386
Senior	77,823	84,442	92,414	102,055	109,036	109,695	110,305	107,773
Fifth year	5,419	5,520	5,731	5,706	6,722	6,236	6,159	5,928
Total part-time	25,811	32,227	32,825	31,940	35,061	34,864	36,673	38,137
Engineering technology programs								
Total full-time	38,347	47,755	48,847	37,198	60,096	48,218	49,210	NA
First year	18,102	22,127	21,483	14,123	23,995	17,030	18,098	NA
Second year	10,985	13,302	14,434	11,505	16,828	13,856	13,590	NA
Other full-time associates	455	784	541	221	709	785	344	NA
Bachelor of engineering technology								
Third and later years	8,805	11,542	12,389	11,349	18,719	16,686	17,178	NA
Total part-time	15,271	17,395	16,639	13,442	24,134	21,341	18,781	NA

¹ Preliminary.

Note: NA = Not available.

SOURCE: Engineering Manpower Commission, *Engineering and Technology Enrollments, Fall 1985*, Part I (p. vi) and Part II (p. v), 1986, and unpublished tabulations.
Science & Engineering Indicators—1987**Table 2-2. Freshmen plans**

	1982	1983	1984	1985	1986
Percent					
Highest degree planned:					
Ph.D or Ed. D.	8.2	8.5	9.2	9.2	9.7
Master's	30.5	30.4	31.2	31.6	33.0
B.A. or B.S.	38.3	36.5	37.6	38.2	36.8
Probable major:					
Biological sciences	3.7	3.8	4.2	3.4	3.9
Engineering	12.6	11.7	11.0	10.7	10.9
Physical sciences	2.5	2.5	2.6	2.4	2.4
Social sciences	5.8	6.1	6.7	7.6	8.0
Computer sciences	4.4	4.5	3.4	2.3	1.9
Business	24.2	24.4	26.4	26.8	26.9
Education	6.0	6.0	6.5	7.1	8.1
Arts and humanities	8.2	7.9	7.7	8.3	9.0
Professions	13.3	14.4	14.1	12.9	11.7
Probable career occupation:					
Computer programmer or analyst	8.8	8.5	6.1	4.4	3.5
Scientific researcher	1.5	1.5	1.5	1.4	1.4
Engineer	12.0	10.8	10.4	10.0	9.7

SOURCE: Cooperative Institutional Research Program, *The American Freshman: National Norms for Fall, 1986*, and reports with the same title for 1982-85, University of California at Los Angeles and American Council on Education (December, 1986)

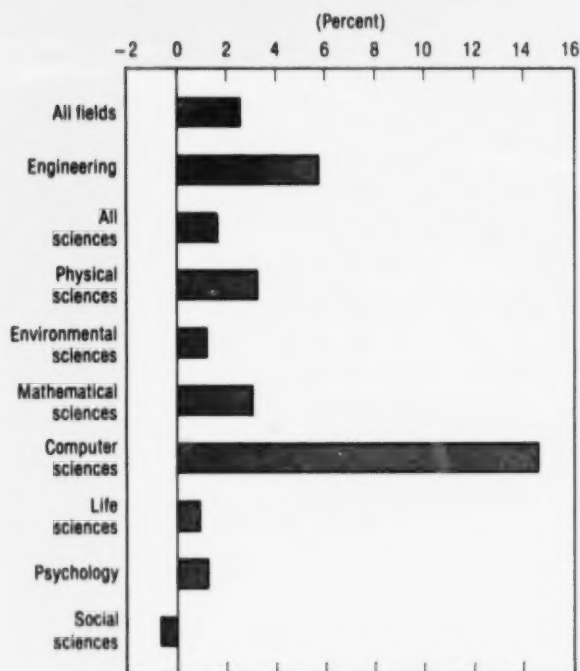
Science & Engineering Indicators—1987

annual rate of 2.6 percent from 1980 to 1986 (see figure 2-1), although full-time U.S. citizens in doctorate-granting institutions increased only 0.5 percent during this period. (See appendix table 2-3.) Across-field differences in enrollment patterns continued to be considerable, however. For instance, graduate enrollments in computer science led the increases at about 15 percent per

year for the past 6 years. Similarly, engineering enrollments continued to grow strongly. Graduate enrollments in the social sciences, on the other hand, declined at an average annual rate of 0.6 percent since 1980. (See appendix table 2-2.)

Graduate enrollment trends also differ when citizenship, institutional level, and student status are taken

Figure 2-1.
Average annual percentage change in
graduate enrollments, by field, 1980-1986



See appendix table 2-7

Science & Engineering Indicators — 1987

into account. For example, full-time graduate S/E enrollment of U.S. citizens in doctorate-granting institutions increased 1.3 percent in 1986 over 1985, compared to a 6-year trend of 0.5 percent. (See appendix table 2-3.) Foreign citizen enrollments, in contrast, increased 9.7 percent in 1986, compared to a 6-year trend of 6.9 percent. (See appendix table 2-4.) This increase (2.6 percent) in total graduate S/E enrollments was concentrated in doctorate-granting institutions; S/E enrollments in master's degree-granting institutions decreased -1.1 percent. (See appendix table 2-5.)

Part-Time Graduate Enrollments. One of the more persistent S/E enrollment trends is the increased tendency to pursue graduate S/E studies on a part-time basis. Full-time S/E graduate enrollment increased in all institutions at an average annual rate of 1.9 percent from 1980 to 1986. (See figure 2-2.) Part-time enrollments, in contrast, increased at a 3.7-percent rate. The trend is stronger in master's degree-granting institutions. Full-time enrollments at these institutions have changed very little since 1980; part-time enrollments in these schools, on the other hand, increased at an average annual rate of 5.6 percent since 1980. In 1986, 68 percent of S/E graduate enrollment in doctorate-granting institutions was full-time, compared with only 31 percent in master's-granting institutions. (See appendix table 2-5.)

Postdoctorates. S/E postdoctorates pursuing advanced study and research in doctorate-granting institutions increased at a rate of 6.8 percent from 1985 to 1986, an increase over the 1980-86 average annual growth rate of 4.6 percent. (See appendix table 2-6.) From 1985 to 1986, growth in postdoctorate appointments was most notable in the environmental sciences (11.5 percent), physical sciences (6.6 percent), and life sciences (7.5 percent).

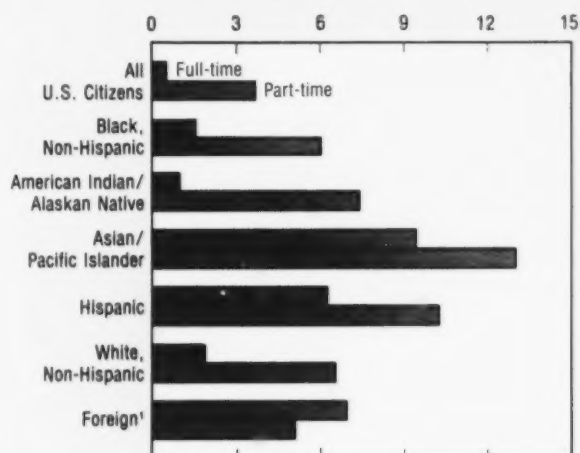
Enrollments by Gender. One of the strongest trends in graduate S/E enrollments during the past decade has been the increasing enrollment rates of women. These increases, coupled with swelling enrollments by foreign nonresidents (see below), have helped offset declines in enrollment stemming from a shrinking population pool of graduate-age students.

Women have increased their matriculation rates in virtually all S/E fields. (See appendix table 2-7.) Average annual female enrollment growth from 1980 to 1986 has been particularly strong in computer science (15.8 percent), engineering and most of its subfields (12.6 percent), and in the physical sciences (7.2 percent). Male enrollment growth in these fields for the same years was 5.0 percent, 14.2 percent, and 2.4 percent, respectively.

Despite these impressive growth rates, women still participate in S/E graduate education in numbers far below their share of the general population. S/E enrollments in 1986 by gender, for full- and part-time study in all institutional types, show that considerable progress is still needed to achieve equal participation by men and women in U.S. S/E higher education.

Enrollments by Racial/Ethnic Status. The overall college-going rates of blacks, Hispanics, Asian-Americans, and

Figure 2-2.
Average annual percentage change in
graduate S/E enrollments, by citizenship,
racial/ethnic background, and enrollment
status, 1980-1986



¹Part-time trend is for 1982-1986

See appendix tables 2-2 and 2-7. Science & Engineering Indicators — 1987

Native Americans differ markedly from those of the white population. These rates also differ by gender across racial/ethnic groups. (See figure O-18 in Overview.) Whites (excluding white Hispanics) aged 18-21 have, from 1978 to 1985, slowly increased their enrollments in higher education to near 40 percent for both genders. (White males, however, have still not achieved their enrollment rates of the early 1970's.) Black males are increasing their college enrollment rates while black female college enrollment is holding steady. (See appendix table 2-1.) In 1985, black males and females aged 18-21 attended college at 26 percent and 24 percent, respectively.

Blacks are far less likely than whites to continue their education at the graduate level, and a smaller percentage of them enroll in S/E programs in graduate school. Moreover, full-time enrollment of black U.S. citizens in graduate S/E programs remained unchanged in 1986 over 1985, compared with an increase in white U.S. citizen enrollment of 1.7 percent. Part-time enrollment of blacks decreased in 1986 over the previous year by 2.4 percent. Hispanic U.S. citizens increased full-time enrollments in 1986 by 5.1 percent, but decreased part-time S/E study by 4.4 percent. (See appendix table 2-2.)

Black enrollment patterns differ from white enrollments in several ways. In 1986, blacks were more likely to be enrolled on a part-time basis than whites; 49 percent of black U.S. citizens in all institutions were enrolled on a part-time basis while the equivalent figure for whites was 41 percent. Blacks were less likely than whites to be enrolled in doctorate-granting institutions; blacks also were less likely than whites (10.8 percent versus 19.0 percent) to be enrolled in graduate-level engineering programs. (See appendix tables 2-2 and 2-3.)

One of the more noticeable trends in graduate S/E enrollment has been the strong interest in these fields by U.S. citizens from Asian backgrounds. Total S/E graduate enrollment growth of Asians/Pacific Islanders averaged 13 percent from 1982 to 1986. (See appendix table 2-2.) These students select engineering, computer science, and mathematics at rates higher than any other U.S. racial/ethnic group. Their enrollment rates in engineering equaled those of foreign students in graduate S/E engineering in 1986, and they were more likely than whites to choose engineering (36 percent versus 19 percent).

Enrollments by Citizenship. One of the most persistent trends in S/E enrollment patterns at U.S. institutions has been the increasing numbers of non-U.S. citizens. While at the undergraduate level, non-U.S. citizens made up less than 5 percent of the total student population in 1982, on the graduate level—and in S/E fields—the role of foreign students is much more evident.

Foreign students represented 19.8 percent of all S/E graduate students in all institutions in 1986. (See appendix table 2-2.) They were even more heavily represented in doctorate-granting institutions (28 percent) and in at least three fields at these institutions—mathematics, engineering, and computer science—made up about 40 percent of the total graduate enrollment. (See figure O-20 and appendix table 2-4.) Most of these foreign S/E graduate students were studying full-time; this was at least in part because of Immigration and Naturalization Service

regulations requiring full-time study by persons on student visas.

Since 1980, full-time S/E graduate enrollments of U.S. citizens in all institutions have increased at an average annual rate of 0.4 percent, while non-U.S. citizen enrollments have increased at an average annual rate of 7.0 percent. This illustrates the extent to which U.S. institutions offering S/E graduate degrees have depended on foreign student enrollment for much of their expansion. Higher education systems in other industrialized countries have also experienced increased enrollments of foreign students. This trend indicates an "internationalization" of the higher education services market, with the industrial countries providing their educational services to citizens from less developed countries. In the U.S. in 1984-85, for example, 12 percent of the foreign students were from Africa, 14 percent from Latin America, 17 percent from the Middle East, and 42 percent from South and East Asia. (See appendix table 2-8.) While the U.S. has the largest number of foreign students among the industrialized nations, it ranks 18th in terms of the proportion of students from foreign countries."

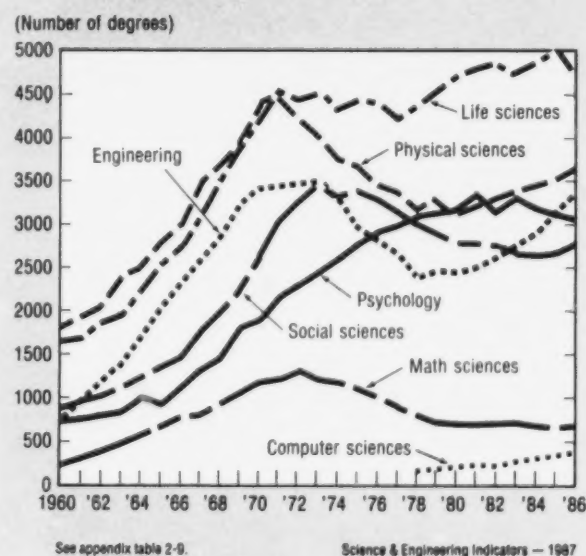
SCIENCE AND ENGINEERING DEGREES

Overall Degree Trends

In 1986, 530 more Ph.D.'s in all S/E fields combined were awarded by U.S. educational institutions than in

*NSF (1987b), p. 7.

Figure 2-3.
Science and engineering doctorates



1985. (See figure 2-3.) This increase was largely accounted for by engineering Ph.D.'s, which increased by 7 percent over 1985; science Ph.D.'s increased by 2 percent. Computer science and the physical sciences led the increases, and mathematical sciences Ph.D.'s were up over the previous year for the first time in 14 years.⁷

While the total number of Ph.D.'s awarded by U.S. institutions in all fields has changed little since 1979, the proportion of those awarded in S/E fields has increased—by about 4 percentage points—to about 59 percent. (See appendix table 2-10.) This ratio of S/E doctorates to all doctorates is, however, below that of approximately 65 percent attained in the early 1960's. And in absolute numbers, both total Ph.D.'s awarded and Ph.D.'s in S/E fields still remain below the peak years of 1973 and 1972, respectively.

Baccalaureate and master's degree awards in S/E fields⁸ have also increased over the past few years. At the baccalaureate level, the total number of S/E degrees earned increased in 1979 after 5 years of decline. Master's awards in S/E fields increased beginning in 1981 after a similar period of decline. (See appendix table 2-10.)

In 1984, S/E degrees as a percentage of all baccalaureates attained their peak ratios of the late 1960's (about 32 percent). In contrast, however, master's S/E degrees as a percentage of all master's were 23 percent, far below the 30-percent ratio of the 1960's.

Time-to-Ph.D.

One of the more persistent trends in S/E higher education is the increasing length of time incurred between the baccalaureate and doctorate degrees.⁹ The median number of years between receiving the bachelor's degree and earning the doctorate has increased since 1974 in the physical sciences (by about 6 months), engineering (3 months), life sciences (15 months), and social sciences (24 months). (See appendix table 2-11.)

Ph.D.'s by Citizenship

The number of U.S. citizens earning doctorates in S/E fields has been declining since at least 1975.¹⁰ In contrast,

Ph.D. awards to non-U.S. citizens have increased steadily; these largely account for increases in total Ph.D. output over the past 8 years.

Foreigners study in the U.S. on either permanent resident visas or temporary (student) visas. In 1985, the percentage of total S/E Ph.D.'s awarded to foreign-born students hit an all-time high at 26 percent, with individual field ratios reaching (for example) 55 percent in engineering and 26 percent in the physical sciences.¹¹

Most foreign students have temporary visas, and about 50 percent of these plan to stay in the U.S. to work. About 85 percent of those students with permanent visas plan to remain in the U.S.¹² While these percentages have not changed in recent years, the number of such foreign-born Ph.D. earners planning to remain in the U.S. has increased.

S/E Degrees by Gender

Female participation in science and engineering, as indicated by S/E degrees awarded to women, has increased steadily over the past 25 years. (See appendix table 2-10.) In 1985, women earned 38 percent of all S/E bachelor's degrees, 30 percent of S/E master's degrees, and 25 percent of S/E Ph.D.'s. These percentages were up from 16 percent, 10 percent, and 7 percent, respectively, in 1960.

In contrast to these impressive increases in percentages of S/E degrees awarded to women at various levels, the declining rates as the level of study increases show that women are less likely than men to continue in S/E study. However, the objective of increasing the rates at which women continue S/E education was clearly achieved through 1986, when women received 26 percent of all S/E Ph.D.'s earned by U.S. citizens, compared with 9 percent in 1970.¹³ In recent years, however, increases in the percentage of S/E Ph.D.'s obtained by women have slowed.

S/E GRADUATE STUDENT SUPPORT

One indicator of the value society places on science and engineering is the financial support provided to students in these fields. Especially at the expensive, higher levels of education, changes in support patterns can reflect society's perception of the need to invest in the higher education of future scientists and engineers.

There are two types of indicators of support for graduate education in science and engineering: (1) reports from students and institutions about the main sources of support for graduate study, and (2) reports from Federal

⁷The discussion in this section of trends in degree attainment is restricted to broad disciplinary fields and comparisons among these fields. Changes in degree attainment patterns within a field may be important, but they are beyond the scope of this analysis. For example, a recent study of degrees awarded in psychology found that the fastest growth has occurred in the number of psychologists trained as health service providers, whereas training of academic or research-oriented psychologists has declined. (See American Psychological Association, 1985.) Another example is the increasing importance of the Ph.D., compared to the M.D., in biomedical research. (See National Science Board, 1986a, pp. 97-98.)

⁸Disciplinary practices regarding the master's degree vary. Master's degrees may be considered a terminal degree in some fields, while in Ph.D. programs the master's may or may not be part of the normal path to the Ph.D.

⁹National Research Council (1985), pp. 7-8.

¹⁰NSF (1987b).

¹¹National Research Council, 1986b.

¹²NSF (1987b), p. 30.

¹³Ibid., p. 97.

agencies on their obligations for various activities in academic science and engineering.¹⁴

Source of Support

Approximately 71 percent of the full-time S/E graduate students in U.S. doctorate-granting institutions received some form of financial aid in 1986; this percentage has not changed more than 1 or 2 points since 1980. (See appendix table 2-12.) When changes in the sources of graduate student financial aid are contrasted with enrollment changes over the same period, some noticeable shifts in source of support become evident. While full-time S/E enrollments increased at an annual average rate of 2.0 percent from 1980 to 1986, the number of students reporting the Federal Government as the main source of assistance decreased 0.5 percent over the same period, although the 1985-86 percentage change was positive. (See below.) In contrast, students reporting their main support from some source other than the Federal Government or self-support increased at an average annual rate of 3.8 percent from 1980 to 1986. (See figure 2-4.) The number of students who paid for most or all of their own graduate S/E education increased from 1980 to 1986 at an average annual rate of 1.1 percent;¹⁵ this growth was slightly behind that in enrollments.

Over all science and engineering fields, the yearly proportion of full-time graduate students reporting their main support from Federal sources has declined, going from 23 percent in 1980 to 20 percent in 1986. However, the number reporting Federal support in 1986 was up by 4.9 percent from 1985 across all S/E fields combined. Support of graduate students in engineering and computer science led these increases at 10.5 percent and 15.9 percent, respectively.

Federal support increased as the main source of support in the environmental and agricultural sciences in 1986 over 1985, in contrast to overall negative trends in such support since 1980. Federal sources as the main support for full-time graduate S/E students in the social sciences continued its downward trend.

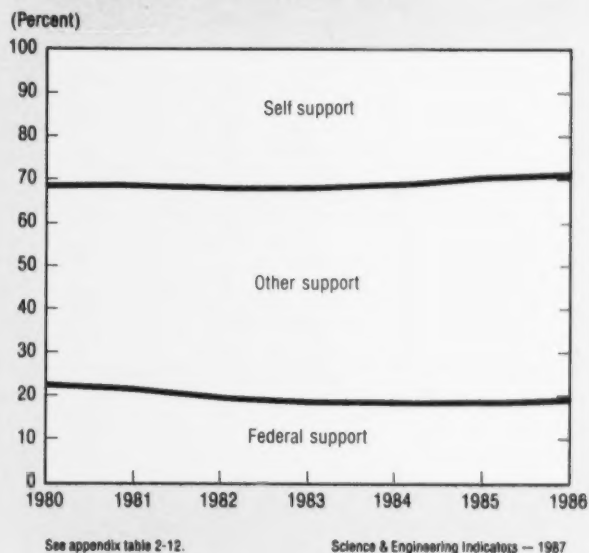
¹⁴Both of these indicators have limitations. For example, the census of academic institutions offering S/E doctorates only reports on the source and type of major support for the graduate student. Since students often attend graduate study with a package of financial aid from different sources and of different types, many of these sources are not reported, leading to under-reporting of virtually all support sources. Additionally, the data contain no dollar value of the support received.

Another source of data on student financial aid is the reports made by students upon attaining their doctorates. This survey is a full census of the population of students receiving a doctorate in an S/E field each year. Again, however, the data are limited to the main source of support and ignore the amount of financial aid received.

The problem with the second type of indicator—Federal obligations for academic science and engineering support on the graduate level—is that it covers only a portion of the Federal support provided for graduate S/E study. While the indicator captures Federally funded fellowships, traineeships, and training grants, it misses the substantial monetary support of graduate S/E students with research assistantships.

¹⁵Federally guaranteed student loans may be included in this figure.

Figure 2-4.
Major source of support of full-time
S/E graduate students in doctorate-granting
institutions



Financial Support by Type

The decline in fellowships and traineeships noted in *Science Indicators—1985* has been reversed in recent years. Such awards to graduate S/E students increased 1.2 percent from 1985 to 1986, although the 1980-86 trend remained negative. (See appendix table 2-13.) The most noteworthy increases from 1985 to 1986 were observed in computer science (10.7 percent), engineering (3.8 percent), and the social sciences (4.3 percent). Research assistantships have shown strong growth as a preferred mechanism of support in all fields, but especially in engineering (14.3 percent) and computer science (13.1 percent).

Support by Gender and Source

While women have increased their share of earned doctorates over the past decade, their proportions in S/E fields—both as graduate students and as doctorate recipients—are still far below those of men.

In a world of equal qualifications, equal interests, and unbiased support patterns, financial support of males and females in S/E graduate education should mirror the proportions of male and female enrollment. In practice, however, this ideal is not achieved. (See appendix table 2-22.) Several differences become apparent when male and female graduate S/E support are compared by funding source and field of study. The Department of Defense (DoD) and foreign sources provide more financial aid to

graduate S/E males, at least in part because of male domination in the fields of concern to the armed forces and in those chosen by foreigners studying in U.S. institutions. The Department of Health and Human Services (HHS), in contrast, most often funds females out of proportion to their share of enrollment in most fields. This pattern is also true of the National Institutes of Health, part of HHS. The National Science Foundation, in contrast, more heavily funded males than would be expected from their enrollment shares.

Across all sources of main support, computer science and mathematics stand out as fields in which women receive less funding than their proportions in the fields would suggest. Females also listed "self support" as the main source of their graduate education funds more often than their enrollment shares alone would predict. (See appendix table 2-22.)

INSTITUTIONS OF S/E HIGHER EDUCATION

This section discusses two types of indicators. The first is concerned with the relationships among various groups of institutions: those which perform the most research and development (R&D), those which award S/E degrees at various levels, and those which award S/E baccalaureates to students who then go on to obtain S/E Ph.D.'s at some other institution. A second set of data shows characteristics of the faculties in the Nation's institutions of higher S/E education: their main activities on campus, their age distributions, and changes in their distribution across S/E fields in recent years.

The Producers of S/E Doctorates

Two recent analyses¹⁶ of the baccalaureate origins of S/E Ph.D.'s found that:

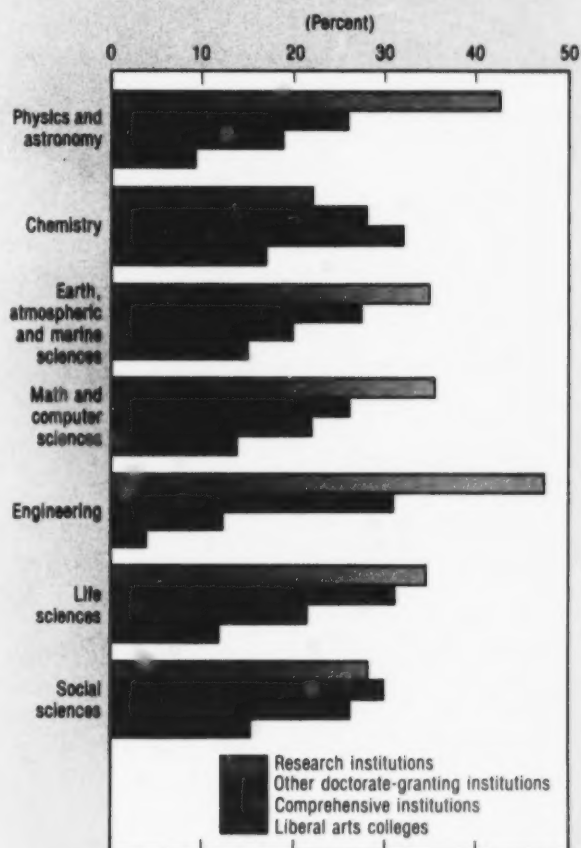
- Most S/E Ph.D.'s earned their baccalaureates at research-intensive and other doctorate-granting institutions;
- The proportion of S/E Ph.D.'s earning their baccalaureates at research-intensive institutions has declined over the past few decades;
- The baccalaureate origins of Ph.D.'s differ by gender and racial/ethnic group; and
- A small group of selective small universities and colleges produces relatively large percentages of their baccalaureates who go on to obtain S/E Ph.D.'s.

These results are expanded on in the following paragraphs.

Large Producers of S/E Ph.D.'s. Using a slight modification of the "Carnegie" scheme for classifying institu-

¹⁶National Research Council (1986b); and Lois Peters, unpublished tabulations.

Figure 2-5.
Distribution of 1984 S/E Ph.D.'s, by
institutional type of baccalaureate-granting
institution¹



¹Omits specialized institutions and institutions not classified by type.

See appendix table 2-14.

Science & Engineering Indicators — 1987

tions,¹⁷ the National Research Council found that of all S/E Ph.D.'s awarded in 1984 to persons who attended

¹⁷The scheme used was as follows:

- Research-intensive universities: the 50 leading universities in terms of Federal financial support, plus 50 or more Ph.D.'s awarded in 1973-74.
- Other doctorate-granting universities (128 institutions): 20 or more Ph.D.'s awarded in 1973-74, or 10 or more in at least three fields.
- Comprehensive institutions (548 institutions): liberal arts programs plus at least one other professional or occupational program; highest degree awarded is the master's, or the Ph.D. program is extremely limited.
- Liberal arts schools (430 institutions): predominantly bachelor's level with a strong liberal arts tradition.
- Other (80 institutions): exclusively or almost exclusively technical or professional in such areas as medicine, theology, business, etc.

U.S. undergraduate institutions, 63 percent of their undergraduate degrees had been earned at research-intensive and other doctorate-granting institutions. (See figure 2-5.) The baccalaureates of 58 percent of 1984 physical sciences Ph.D.'s, 78 percent of engineering, 65 percent of life sciences, and 58 percent of social sciences, had been awarded by these research-intensive institutions.

Engineering Ph.D.'s were the most likely to have earned their baccalaureates at Ph.D.-granting institutions. In contrast, chemistry Ph.D. earners were more likely than any other group of scientists to have obtained their baccalaureates at "comprehensive" or liberal arts colleges. These two types of institutions awarded 49 percent of the baccalaureates to U.S. citizens who obtained Ph.D.'s in chemistry in 1984.

Similar findings were made using a different institutional classification scheme and different time frame.¹⁸ This analysis divided the baccalaureate-granting schools as follows: schools granting more than 40 S/E Ph.D.'s in 1981-82, 40 or fewer, up to the master's degree, up to the bachelor's degree, and foreign institutions. (See appendix table 2-15.) This analysis found decreasing percentages of baccalaureates awarded to S/E Ph.D. earners by the large Ph.D.-granting institutions between 1963 and 1983. Considerable increases in the importance of non-U.S. institutions in producing undergraduates who eventually obtain their Ph.D.'s in the U.S. were found in engineering and the physical sciences.

Women S/E Ph.D. earners from 1983 to 1985 were slightly less likely to have obtained their baccalaureates at research-intensive or other doctorate-granting institutions than men (55 percent versus 59 percent). (See appendix table 2-16.) Black S/E Ph.D. earners were considerably less likely to have attended these institutions than whites (40 percent versus 61 percent).

"Productive" Producers of S/E Ph.D.'s. The data discussed above considered only the total output of the undergraduate institutions in terms of the number of baccalaureate earners who eventually obtained Ph.D.'s. With this approach, the baccalaureate "source" institutions are dominated by the larger universities. Another approach is to compare the percentage of a school's baccalaureate earners who go on to obtain Ph.D.'s.

The National Research Council compared the output and productivity of specific undergraduate institutions for the 1984 Ph.D. cohort. Across all fields, the study found that of the 30 leading undergraduate institutions granting at least 50 baccalaureates¹⁹ in 1974, only 1 of these 30 was a primarily undergraduate school (City University of New York-Brooklyn), based on total output of baccalaureates going on to obtain the Ph.D. in all fields. (See appendix table 2-17.) In contrast, of the 30 most "productive"²⁰ undergraduate institutions in 1974, 19 of

these schools were neither research-intensive nor other doctorate-granting schools.

The same analysis identified "productive" undergraduate institutions which award undergraduate degrees to eventual S/E Ph.D. recipients out of proportion to their size and importance in the research and development community. For example, 6 of the 10 most "productive" producers of baccalaureates for 1984 Ph.D.'s in the physical sciences were primarily bachelor's institutions or specialized schools. Corresponding counts were 4 out of 10 for engineering, 4 of 10 for the life sciences, and 8 of 10 for the social sciences. (See appendix table 2-18.)

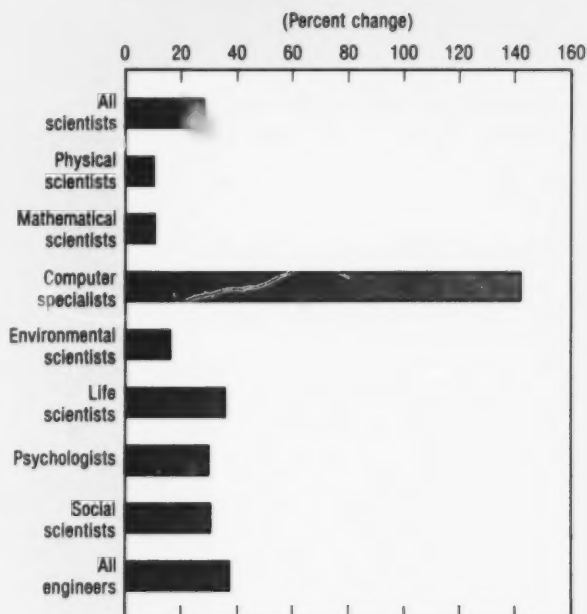
S/E Higher Education Facilities

U.S. institutions of higher education²¹ employed 202,000 doctoral scientists and engineers in 1985. Of these, 180,000 were doctoral *scientists*, about 54 percent of the total doctoral scientists employed in the U.S. The approximately 22,000 doctoral engineers employed by 4-year institutions represented some 33 percent of the total U.S. engineering workforce with Ph.D.'s in 1985.

Virtually all of the major S/E fields have experienced growth in the academic employment of Ph.D.'s (see figure 2-6), although at different rates of growth. Four-year

²¹Defined here as 4-year colleges and universities only.

Figure 2-6.
Growth in academic employment of
doctoral scientists and engineers
between 1977 and 1985



See appendix table 2-19.

Science & Engineering Indicators — 1987

¹⁸Lois Peters, unpublished tabulations.

¹⁹The National Research Council analysis used a cut-off of at least 50 baccalaureates in order to avoid domination by the very small, specialized institutions. See National Research Council (1986b).

²⁰In terms of the number of baccalaureates from a particular school who go on to obtain Ph.D.'s. A "productivity" measure is derived by dividing the Ph.D. earners with a baccalaureate from a specific school by the number of baccalaureates produced by that school.

institutions increased the employment of doctoral computer scientists by 142 percent from 1977 to 1985, a far higher total growth rate than for any other major field. Other fields with considerable increases since 1977 included the life sciences (35.4 percent), engineering (36.9 percent), the social sciences (30.3 percent), and psychology (29.7 percent). (See appendix table 2-19.)

The increase in the employment of doctoral scientists and engineers by 4-year institutions has been accompanied by an increase in the research and development activities of these academic employees. Between 1981 and 1985, the percentage of doctoral scientists and engineers on 4-year campuses who reported teaching as their primary activity increased at a *slower* rate than total employment growth in all major fields except computer science. In contrast, the proportions of doctoral scientists and engineers at 4-year schools reporting R&D activities as their primary work emphasis increased at rates *greater* than employment growth in all fields except computer science, the life sciences, and psychology from 1981 to 1985. (See appendix table 2-20.)

Computer science led most trends from 1981 to 1985, no doubt because of the rapid transformation and stabilization of this field on the Nation's campuses. In those 4 years, computer science experienced:

- A 79.0-percent growth in the number of Ph.D. holders reporting teaching as their primary activity;
- A 73.5-percent growth in the number of Ph.D. computer scientists employed at 4-year institutions; and
- A 64.4-percent growth in the number of Ph.D. computer scientists reporting R&D as their primary activity on campus, compared with the next highest such

increases of 23.9 percent by engineering Ph.D.'s and 22.5 percent by mathematics Ph.D.'s.

The S/E doctoral faculties of the Nation's 4-year institutions also held, in general, higher rank in 1985 than in 1981. (See appendix table 2-21.) In 1985, proportionately more doctoral faculty members held the rank of full professor than in 1981 in all large fields except computer science and engineering. Fields experiencing increases in the proportions holding the rank of full professor display in general decreasing proportions holding either associate or assistant professor status. Only computer science, mathematics, and engineering showed increases in the proportions holding assistant professorships in 1985 over 1981, because of the more recent growth and increased new hiring in these fields.

The age distributions of doctoral faculties reflect the increases in academic rank discussed above. (See appendix table 2-19.) In all fields combined, the proportions younger than 40 years have decreased since 1977. When observed field by field, mathematical scientists and engineers—as might be expected from the recent growth of these fields—have shown slight increases in the proportions of doctoral faculty 30 years or younger. The computer/information sciences, which might for the same reason also have been expected to show an increasing proportion of relatively younger faculty, have in fact experienced a decrease in the *proportions* of faculty under 40 years and significantly increased the proportion between 40 and 49 and more than 60. This unexpected trend in age distribution may be because of the reputed large amount of field switching into computer science from other fields.

REFERENCES

American Council on Education, *Towards a National Policy for Undergraduate Science Education* (Washington, DC: American Council on Education, n.d.).

American Psychological Association, Committee on Employment and Human Resources, *The Changing Face of American Psychology* (Washington, DC: American Psychological Association, 1985).

Carnegie Foundation for the Advancement of Teaching, *Sustaining the Vision* (Princeton: Carnegie Foundation for the Advancement of Teaching, 1985).

Council of Graduate Schools, *Recent Developments in Graduate Programs*, proceedings of October 13, 1982, conference (Washington, DC: Council of Graduate Schools, n.d.).

Engineering Manpower Commission, *Engineering and Technology Enrollments, Fall 1985, Parts I and II* (Washington, DC: American Association of Engineering Societies, 1986).

Government-University-Industry Research Roundtable and the Franklin Institute, "Nurturing Science and Engineering Talent: A Symposium," briefing papers for a symposium held at the Franklin Institute, Philadelphia, September 29, 1986.

Government-University-Industry Research Roundtable and the Franklin Institute, "Nurturing Science and Engineering Talent: a Symposium," briefing papers for a symposium held at the Franklin Institute, Philadelphia, September 29, 1986.

Hauptman, A.M., *Students in Graduate and Professional Education: What We Know and Need to Know* (Washington, DC: The Association of American Universities, 1986).

Lee, V., *Access to Higher Education: The Experience of Blacks, Hispanics, and Low Socio-Economic Status Whites* (Washington, DC: American Council on Education, 1985).

National Research Council, *The Access and Success of Blacks and Hispanics in U.S. Graduate and Professional Education* (Washington, DC: National Academy Press, 1986a).

National Research Council, *Doctorate Recipients from U.S. Universities, 1984* (Washington, DC: National Academy Press, 1986b).

National Research Council, Panel on Engineering Graduate Education and Research, *Engineering Graduate Education and Research* (Washington, DC: National Academy Press, 1985).

National Research Council, Panel on Undergraduate Engineering Education, *Engineering Undergraduate Education* (Washington, DC: National Academy Press, 1986c).

National Science Board, *Science Indicators—1985* (Washington, DC: Government Printing Office, 1986a).

National Science Board, *Undergraduate Science, Mathematics and Engineering Education* (Washington, DC: Government Printing Office, 1986b).

National Science Foundation, Division of Policy Research and Analysis, "The Science and Engineering Pipeline," mimeo, PRA Report 87-2 (Washington, DC: NSF, 1987a).

National Science Foundation, Division of Science Resources Studies, *Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook*, NSF 86-305, revised (Washington, DC: NSF, 1987b).

Office of Science and Technology Policy, Panel on the Health of U.S. Colleges and Universities, *Report of the White House Science Council* (Washington, DC: Government Printing Office, 1986).

Smith, B.L.R., ed., *The State of Graduate Education* (Washington, DC: The Brookings Institution, 1985).

U.S. Department of Education, Office of Educational Research and Improvement, *The Condition of Education 1986* (Washington, DC: Government Printing Office, 1987).

U.S. Congress, House Committee on Education and Labor, "Education and Training for American Competitiveness Act: Report," Report No. 99-597 (Washington, DC: U.S. House of Representatives, 1986).

Chapter 3

Science and Engineering Workforce

Science and Engineering Workforce

HIGHLIGHTS

- *Employment in science and engineering (S/E) jobs reached 3.9 million in 1986, an average annual increase of 6.3 percent per year since 1976. During this period, employment of scientists grew at a faster rate than that of engineers (7.1 percent per year versus 5.8 percent). Growth in scientific employment was greatly influenced by computer specialists, however, who accounted for about two-fifths of the total increase in scientific jobs. (See pp. 53-54.)*
- *Private industry provided employment for 66 percent (2.6 million) of the Nation's scientists and engineers in 1986, up from 62 percent (1.3 million) in 1976. Educational institutions ranked a distant second with 15 percent (0.6 million) of all S/E employment. Almost 70 percent of those employed in industrial S/E were engineers, while scientists represented more than 84 percent of S/E employment in academia. (See pp. 55, 58.)*
- *Although the percentage of women scientists and engineers in the workforce has steadily increased since 1976, women employed in S/E remained underrepresented in 1986, accounting for only 13 percent of the science and engineering workforce. By comparison, women represent almost one-half of the total U.S. workforce. (See pp. 61-63.)*
- *Blacks remained underrepresented in the S/E workforce in 1986, accounting for only 2.5 percent of all scientists and engineers. In contrast, blacks make up 10 percent of total U.S. employment and 6 percent of the professional and related workforce. (See pp. 63-64.)*
- *Labor market indicators suggest that in 1986 there was generally sufficient demand to accommodate the science and engineering workforce. This was characterized by the high labor force participation rate (94.5 percent) and low unemployment rate (1.5 percent) for scientists and engineers. (See p. 64.)*
- *High-technology industrial growth and the increasing use of high-technology goods and services in the economy as a whole will lead to increasing demand for scientists and engineers in industry. Demand for S/E personnel is expected to increase by 36 percent between 1986 and 2000, with the highest anticipated growth expected for computer specialists (76 percent) and the lowest for chemists (11 percent). (See pp. 67-68.)*
- *The supply of new science and engineering graduates may decline over the next decade because of an expected decrease in the college-age population. Increased participation by women and minorities in undergraduate S/E programs and/or expanded enrollment of older students and foreigners may be required to eliminate potential shortages of new S/E graduates. (See pp. 64, 68-70.)*
- *The United States has a higher proportion of scientists and engineers in the labor force than has Japan (2.8 percent as compared to 2.5 percent). In addition, the U.S. participation of women in S/E is 2.5 times greater than that of Japan. The United States is also graduating more engineers at both the bachelor's and doctorate degree levels. (See pp. 70-72.)*

The more than 4.6 million scientists and engineers¹ employed in the United States in 1986 contribute in countless ways to the welfare and technological progress of the Nation. They are essential to the functioning of our advanced industrial society and have an impact on society disproportionate to their numbers.

The past decade has witnessed a substantial growth in demand for workers in science and engineering activities. New and expanded programs in research and development (R&D), defense, health, and higher educa-

tion all contributed to this growth. There has also been a shift in this decade in the industrial demand composition for S/E personnel as nonmanufacturing industries begin to overtake manufacturing ones as the major employment sector.² These changes have been generally accomplished through a flexible labor force and educational system capable of providing the personnel and training required; an increasing utilization of foreign-origin personnel has also been a significant factor.³

While there were substantial shortages for many S/E occupations in the early 1980's,⁴ there was, by 1986, a sufficient supply of scientists and engineers to meet most

¹See appendix table 3-1. In general, a person is considered a scientist or engineer if (1) the highest degree held is in a science or engineering field, and (2) the person is either employed in a science or engineering job or professionally identifies himself or herself as a scientist or engineer based on total education and work experience.

²See NSF (1987a), back cover.

³NSF (1986a), p. 37.

⁴NSF (1986b), back cover.

of the industrial sector's needs. Within the academic sector, however, low rates of faculty retirement and declining rates of growth in institution size have produced a progressively older science and engineering academic community.⁵ Another persistent problem is a continuing shortage of Ph.D.'s for employment in engineering schools.⁶ Since these patterns are not likely to change in the near future, there is some concern as to the ability of colleges and universities to maintain the high caliber of S/E research and education.

This chapter reviews trends in utilization patterns of scientific and technical personnel, examines the dynamics of the supply of scientists and engineers, discusses recent labor market conditions, and presents forecasts of requirements through the 1990's.

UTILIZATION OF SCIENTIFIC AND TECHNICAL PERSONNEL

Trends in S/E Employment

Trends in the utilization of scientific and technical personnel, when reviewed against the backdrop of other economic developments, provide indicators of national priorities in assigning human resources to science and technology. In the last decade, employment of those in science and engineering jobs has grown more rapidly than have total U.S. employment and overall economic activity: this indicates substantial shifts in national activity patterns toward those related to science and technology. Moreover, this growth has been shared by all S/E occupations, particularly computer specialties. The proportion of scientists and engineers employed by the industrial and educational sectors has continued to increase, while the percentage working in the Federal Government and other sectors has declined.

It is useful to distinguish between the employment of those who are considered scientists and engineers because of their education and experience and the employment of those who have jobs in S/E. For a variety of reasons (mostly "voluntary" ones, such as better pay, promotions, and location preference), some scientists and engineers hold jobs outside their own or related fields. Of the approximately 4.6 million employed scientists and engineers in 1986, 15 percent (700,000) reported that they held jobs outside of science and engineering; scientists (23 percent) are more likely than engineers (8 percent) to hold such positions. (See figure O-10 in Overview.) Being employed in non-S/E jobs does not necessarily mean that these scientists and engineers are underutilized (see p. 65), since their training and education may provide valuable insights on their nontechnical activities. Trends in the numbers of persons employed in science and engineering work relative to all U.S. workers or other economic variables are direct indicators of national priorities for technical compared to nontechnical activities.

The recent emphasis on increasing defense expenditures, levels of research and development expenditures, and growth in demand for high-technology goods and services all would suggest that S/E employment would be expected to claim a higher proportion of overall U.S. employment. The 1986 data confirm this premise, as the U.S. workplace continues its trend of putting greater emphasis on scientific and engineering activities. Between 1976 and 1986, the number of those employed in S/E jobs expanded at a substantially faster rate than did either total employment or overall economic activity as measured by gross national product (GNP). (See table O-1 and figure O-9 in Overview.)

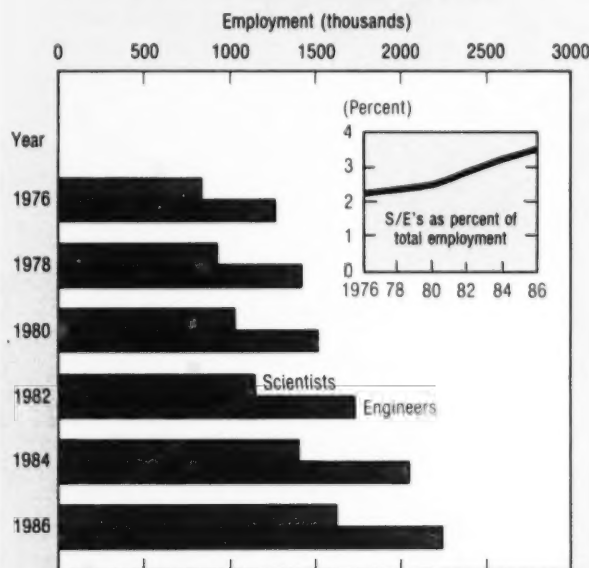
During the last decade, the S/E workforce⁷ nearly doubled, increasing four times as rapidly as total U.S. employment. Science and engineering employment grew by 6.3 percent per year between 1976 and 1986, reaching almost 4 million. (See figure O-11 in Overview.) In the same period, total U.S. employment increased by 2.1 percent per year;⁸ the share of the total workforce devoted to science and engineering increased from 2.4 percent to 3.6 percent. (See figure 3-1.) Finally, real GNP increased at an annual rate of only 2.7 percent between 1976 and 1986.

As indicated above, much of the increase in S/E employment can be attributed to the relatively greater uti-

⁷Includes only those scientists and engineers employed in science or engineering jobs, unless otherwise indicated.

⁸Civilian employment, 16 years of age and over.

Figure 3-1.
Scientists and engineers employed in S/E jobs



See appendix tables 3-1 and 3-2.

Science & Engineering Indicators — 1987

⁵Paula Stephan, as reported in Cunningham (1986), p. 6.

⁶Doigan (1984), pp. 50-55.

lization of scientists and technical personnel in the economy—presumably because of greater scientific and technical sophistication of products and production processes, Government expenditures for defense and other programs requiring significant inputs of S/E talent, and other factors.

Growth in the employment of scientists and engineers between 1976 and 1986 varied substantially across fields. Employment in science occupations increased at an average annual rate of 7.1 percent, reaching more than 1.6 million in 1986. Computer specialists accounted for almost two-fifths of the total employment increases among scientists; if computer specialists are excluded, employment growth for scientists averaged 5.5 percent per year. In 1986, 2.2 million persons held engineering jobs, representing an average annual rate of increase of 5.8 percent. The largest relative growth in engineering was recorded by electrical and astronautical/aeronautical engineers. (See figure O-11 in Overview.) Engineering employment growth would probably have been higher if not for the engineer supply constraints experienced in the late 1970's and early 1980's.⁹

The trends observed during the 1976-86 period have become more pronounced since the early eighties. Between 1980 and 1986, employment of scientists rose at an annual rate of 8.4 percent per year. This growth was still influenced substantially by computer specialists, whose employment increased at an annual rate of 14.2 percent. This growth in the number of computer specialists, compared to the much smaller number of people earning degrees in the field, suggests substantial field mobility. Excluding computer specialists, employment of scientists increased by 6.8 percent per year. Employment of engineers also grew at an annual rate of 6.8 percent during the 1980-86 period. (See appendix table 3-1.)

Employment of S/E doctorate holders reached 400,000¹⁰ in 1985—an increase of 82 percent (5.1 percent per year) since 1973. Since 1981, employment growth of doctoral scientists and engineers has slowed, however, increasing by less than 4 percent per year versus 5.7 percent per year between 1973 and 1981.

While educational institutions have remained the primary source of S/E doctoral employment, the share of Ph.D. scientists and engineers employed by industry has been steadily increasing. Industry employed 31 percent (126,000) of doctoral scientists and engineers in 1985; this was up from 24 percent in 1973. The 212,000 Ph.D. scientists and engineers in educational institutions in 1985 represented about 53 percent of the employed total, down from 59 percent in 1973.

Scientists at the doctoral level continued to outnumber engineers by about five to one in 1985, with growth rates since 1973 varying considerably by field. The physical and mathematical sciences experienced below average annual growth rates, while computer specialties was the

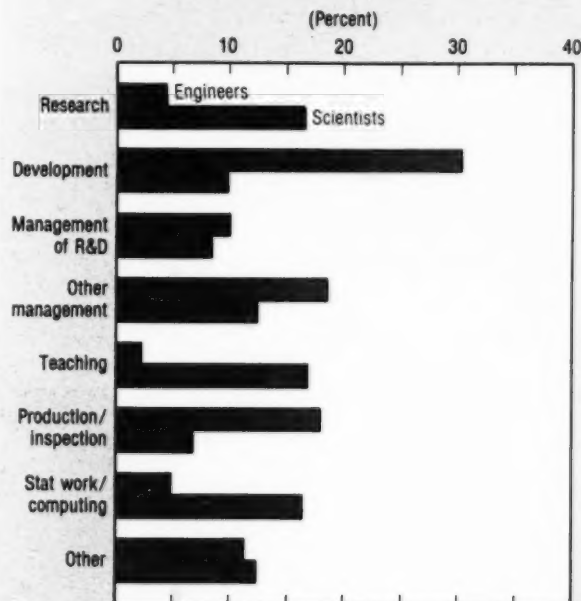
fastest growing field of employment. Between 1973 and 1985, Ph.D. employment in this field grew at an annual rate of more than 15 percent per year, from 2,700 in 1973 to 15,000 in 1985. Almost 60 percent of the increased employment of doctoral computer specialists took place in industry; about 31 percent occurred in educational institutions.

Trends in Science and Technology Activities

Trends in the primary work activities of scientists and engineers are direct indicators of the character of U.S. science and technology. These activities are measured by the number and proportion of those engaged in performing R&D, teaching, and other activities (see figure 3-2), and vary considerably by sector of the economy. Between 1976 and 1986, there was a substantial increase in the relative proportions of scientists and engineers primarily engaged in production, reporting and related activities, and teaching. The proportions of those working in development rose slightly, while the relative proportions of those primarily engaged in general management, R&D management, and research declined.

The number of scientists and engineers primarily engaged in research and development almost doubled in the 1976-86 period. By 1986, R&D was the primary activity of 31 percent of the Nation's scientists and engineers, with an additional 10 percent (about 370,000) working in R&D management. Scientists were more like-

Figure 3-2.
Primary work activities of employed
scientists and engineers: 1986



See appendix table 3-4.

Science & Engineering Indicators — 1987

⁹NSF (1982).

¹⁰Includes 35,900 doctoral scientists and engineers employed in non-S/E activities. All S/E doctorate holders are considered by NSF to be employed as scientists and engineers, even though they may not be employed in S/E activities.

ly than engineers to report research as their primary activity (17 percent versus 4 percent), while engineers were more likely to be involved in development and R&D management (41 percent versus 19 percent). Those holding S/E doctorates were employed in similar proportions. In 1985, 33 percent of doctoral scientists and engineers were working primarily in research and development, while an additional 9 percent cited R&D management as their primary activity.

Employment in teaching activities grew at a somewhat higher rate than did overall S/E employment during the 1976-86 period (8.3 percent versus 6.3 percent per year). About 9 percent of all scientists and engineers reported teaching as their primary work activity in 1986, with scientists more likely than engineers to report teaching as their principal activity (17 percent versus 2 percent). This contrast is partially a result of differences in educational levels: scientists are more likely to hold academic teaching positions than are engineers because a larger proportion of scientists holds doctorates (18 percent versus 3 percent). At the doctoral level, however, 28 percent of scientists and engineers reported teaching as their primary work activity in 1985; this was down from 36 percent in 1973. The decline in the proportion of doctorates reporting teaching as their primary activity is the result of a shift in the concentration of Ph.D.'s from academia to industry (see discussion below on sectoral trends), with the attendant change in work activities.

From 1976 to 1986, production and related activities—including quality control—were among the fastest growing S/E work areas, especially for engineers. The number of scientists and engineers primarily engaged in these activities rose by an average of almost 9 percent per year to about 512,800 in 1986—398,500 engineers and 114,300 scientists.

SECTORAL TRENDS IN THE S/E LABOR FORCE

Private industry was the major employer of both engineers and scientists (66 percent or 2.6 million) in 1986, with engineers more likely than scientists to work in this sector (80 percent versus 48 percent). Industry also employed more than 1.6 million S/E technicians as support personnel. Since 1976, the share of scientists and engineers employed in business and industry has increased by about 5.0 percent, while declining slightly (1.5 percent) for the Federal Government. In 1986, the education sector ranked a distant second as an employer of scientists and engineers (15 percent or almost 573,000), employing 29 percent of all scientists, but only 4 percent of all engineers. (See figures 3-3 and 3-4.)

Sectoral changes have been more pronounced at the doctoral level. Although educational institutions remained the primary employer of doctoral scientists and engineers in 1985, the proportion employed in this sector has declined steadily since the early 1970's, while the industry share has increased. In 1973, 59 percent of all those holding S/E doctorates were in educational institutions and 24 percent were in business and industry; in 1985, these proportions were 53 percent and 31 percent, respectively. (See figure 3-5.)

Figure 3-3.
Distribution of employed scientists and engineers, by sector of employment: 1976, 1986

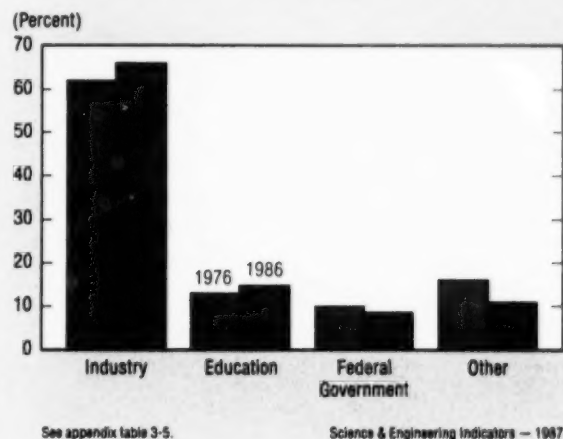
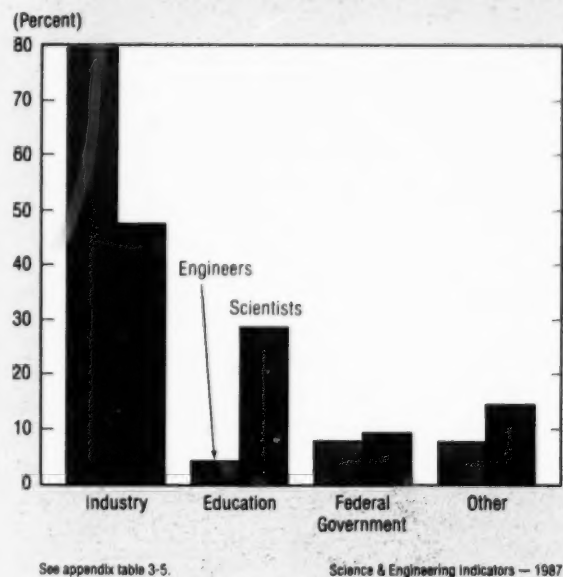


Figure 3-4.
Distribution of employed scientists and engineers, by sector of employment: 1986



Industry

Between 1976 and 1986, business and industry experienced some dramatic changes in both the occupational and industrial distributions of its science, engineering, and technical workforce. Total S/E employment in private

Figure 3-5.
Distribution of employed doctoral scientists and engineers, by sector of employment: 1973, 1985

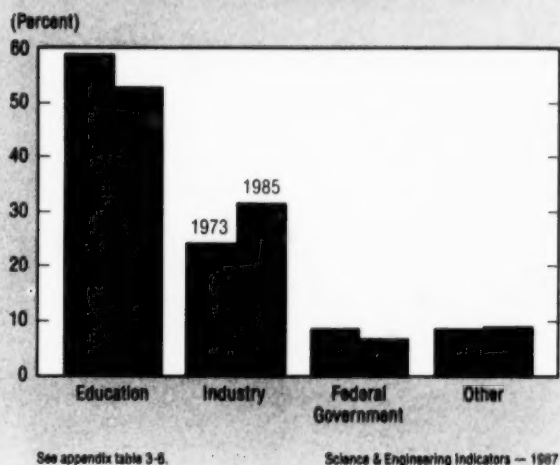
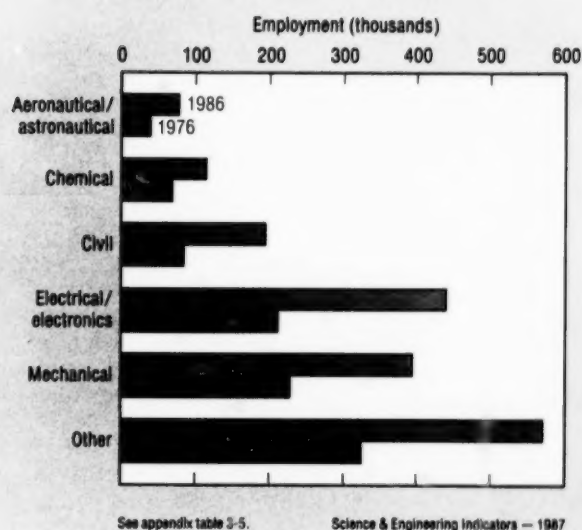
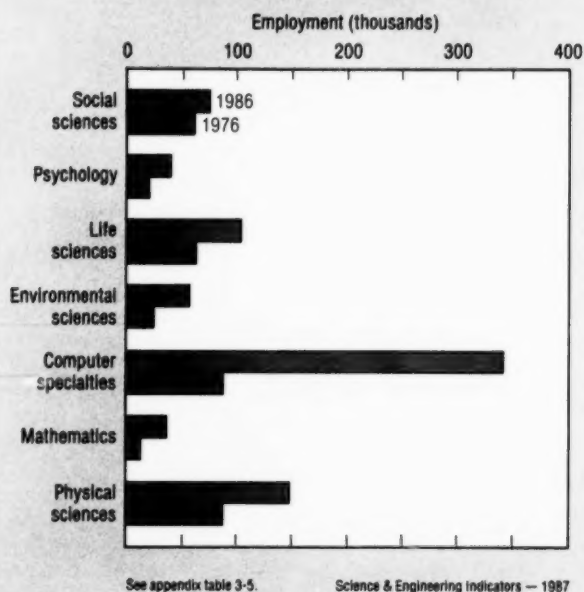


Figure 3-7.
Engineers employed in industry, by field: 1976, 1986



industry increased by an average of 7 percent per year, from 1.3 million in 1976 to almost 2.6 million in 1986. (See figures 3-6 and 3-7.) There was a gradual shift in S/E employment concentration from the manufacturing to

Figure 3-8.
Scientists employed in industry, by field: 1976, 1986



the nonmanufacturing sector,¹¹ with the proportion of scientists and engineers employed in manufacturing industries declining from more than 57 percent in 1977¹² to about 55 percent in 1986. Of the scientists and engineers employed in industry in 1986, about 45 percent worked in the nonmanufacturing sector. (See figures 3-8 and 3-9.)

Much of the increase in S/E employment in the nonmanufacturing sector can be attributed to the rapidly expanding workforce of the service-producing industries; changes in S/E employment within the manufacturing sector, on the other hand, are almost entirely explained by structural change. Even though manufacturing industries experienced little or no growth in total employment levels between 1977 and 1986, science and engineering employment in this sector increased by an average of 4.9 percent per year. This growth—primarily because of the increased dominance of engineers, computer specialists, and mathematical scientists¹³ within these industries—reflected a shift away from the labor-intensive production atmosphere of the seventies to the more “high-tech” and knowledge-intensive environment of the eighties.

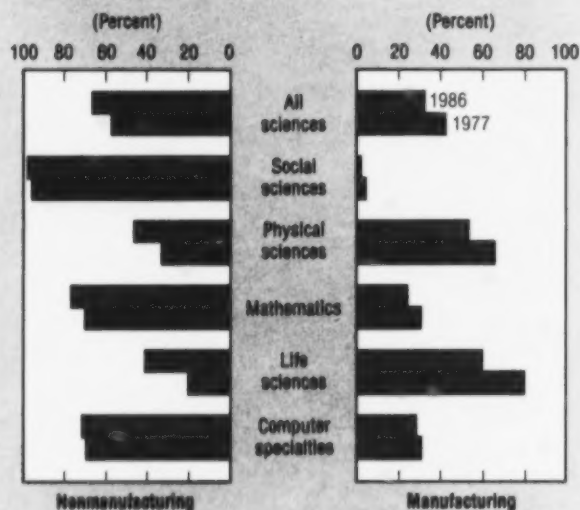
Employment of S/E technicians became increasingly more prominent between 1977 and 1986, increasing from 0.9 million in 1977 to more than 1.5 million in 1986 (5.8 percent growth per year). Almost 80 percent of the increase occurred in the nonmanufacturing sector, again primarily because of the high concentration of service-producing industries in that sector. Computer program-

¹¹See NSF (1987a), back cover.

¹²Earliest year in which data were available.

¹³Zampelli (1986).

Figure 3-8.
Percentage of scientists employed in industry, by
sector and field: 1977, 1986



See appendix table 3-7.

Science & Engineering Indicators — 1987

mer, electrical/electronics technician, and mechanical technician employment all showed substantial gains. (See figure 3-10.)

The shifts in industrial demand for scientists, engineers, and technicians over the last decade are the result of sweeping changes in industry makeup. Between 1976 and 1986, total private nonagricultural employment in the United States grew by almost one-third from 64 million to 83 million. This entire growth was in nonmanufacturing, more notably in non-blue-collar, jobs. However, even though total manufacturing employment did not increase during this period, manufacturing production (as measured by the industrial production index) rose by almost 40 percent.¹⁴

This separation of manufacturing production from manufacturing employment illustrates the transition from mid-1970's labor-intensive industries to 1980's knowledge-intensive industries. For example, it has been estimated that the manufacturing costs of the semiconductor microchip are about 70 percent knowledge—that is, research, development, and testing—and no more than 12 percent labor.¹⁵ Similarly, for prescription drugs, labor represents only 15 percent of the cost, with knowledge representing almost 50 percent.¹⁶ By contrast, in the most fully automated automobile plant, labor would still account for 20 to 25 percent of the costs.¹⁷

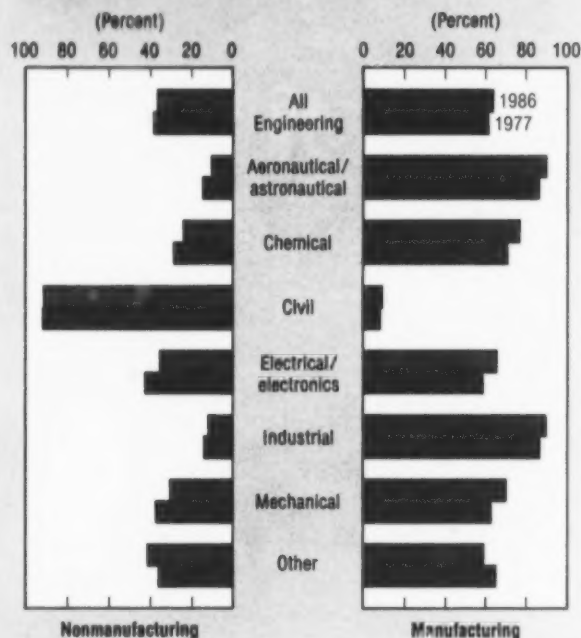
¹⁴Council of Economic Advisers (1987), p. 296.

¹⁵Drucker (1986), p. 778.

¹⁶Ibid.

¹⁷Ibid.

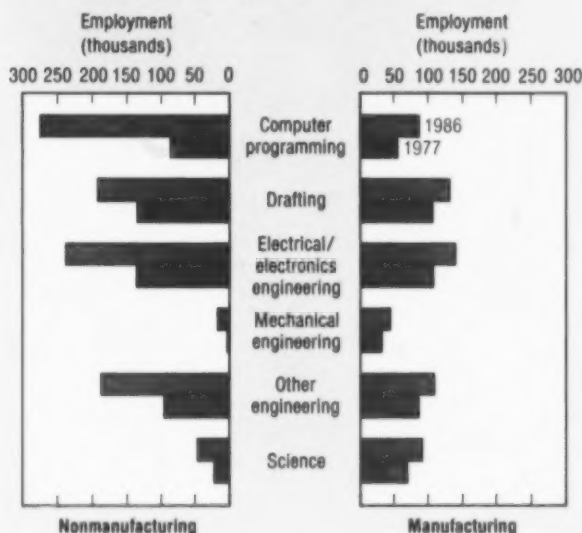
Figure 3-9.
Percentage of engineers employed in industry,
by sector and field: 1977, 1986



See appendix table 3-7.

Science & Engineering Indicators — 1987

Figure 3-10.
Science and engineering technicians employed in
private industry, by sector and field: 1977, 1986



See appendix table 3-8.

Science & Engineering Indicators — 1987

For the last 15 to 20 years, almost the entire shrinkage in manufacturing jobs in the U.S. has occurred in the large companies, beginning with the steel and automobile industry giants. Medium- and small-sized manufacturers have held their own or even added employees. Other developed countries, including Japan, have also been experiencing this reversal of the dynamics of size.

While the transition to a high-tech workforce over the last decade has been accompanied by increasingly greater demands for workers with S/E skills, the supply of such workers has not always been sufficient to meet industry needs. As noted previously, in the late 1970's and early 1980's many firms reported employee shortages in most engineering fields and computer specialties; however, by 1986, there appeared—in general—to be a nearly adequate supply of scientists and engineers. This balance has been brought about in part by field switching and a high reliance on foreign S/E personnel.¹⁸

Educational Institutions

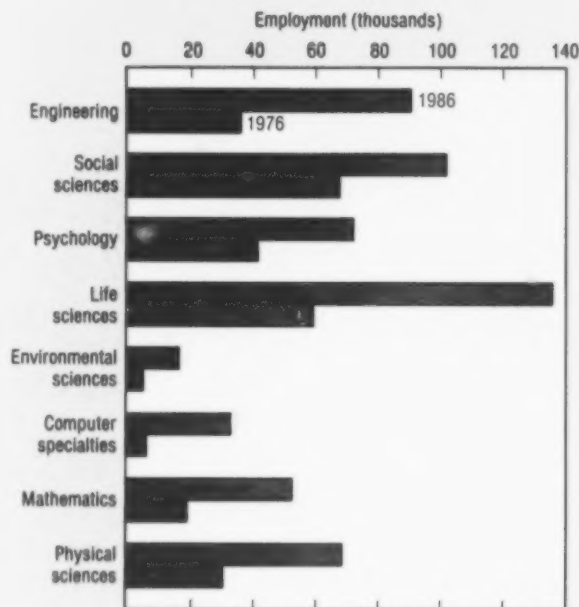
Overall demand for scientists and engineers in educational institutions¹⁹ kept pace with the rate of the economy's growth in demand, increasing from 13 percent in 1976 to almost 15 percent in 1986. The ratio of scientists to engineers also remained constant at about 6 to 1. Of the approximately 573,000 scientists and engineers working in educational institutions in 1986, almost 84 percent were employed in scientific fields; one-half of these were either life scientists or social scientists. Of the 91,000 engineers in this sector, 17,000 were mechanical engineers and 25,000 were electrical/electronics engineers. (See figure 3-11.)

In general, academia experienced the same increasing demand for technical staff as did industry—especially for employees with engineering or computer science degrees. Moreover, because some universities and colleges in the early 1980's were unable to compete with the salaries offered by private industry, they lost faculty members in certain high demand engineering positions.²⁰ Lacking graduate candidates to fill these positions, educational institutions have increasingly relied on foreign academics (as in industry) to maintain their staffing levels.²¹

Federal Government

While the Federal Government was the largest single employer of scientists and engineers in the United States from 1976 to 1986, the proportion of scientists and engineers it employed declined in those years from 10.0 percent to 8.5 percent. In 1986, more than 54 percent of the 334,200 Federal scientists and engineers were employed

Figure 3-11.
Scientists and engineers employed
in educational institutions, by field:
1976 and 1986



See appendix table 3-5.

Science & Engineering Indicators — 1987

in engineering occupations, of which almost one-half were either electrical/electronics or civil engineering. Of the 153,500 scientists in the Federal Government, 40,200 were life scientists and 32,100 were computer specialists.

Federal employment was more technologically intensive than the overall workforce: about 14 percent of all Federal white-collar employees worked in S/E occupations, compared to only 6 percent of total U.S. white-collar employment.²² The Department of Defense (DoD) employed almost one-half of all Federal scientists and engineers, with the Department of Agriculture ranking a distant second (12.0 percent).²³

Other Sectors

Of the 423,700 scientists and engineers not employed in the above sectors in 1986, almost one-half (214,600) worked for State and local governments while 34 percent (143,900) were employed by nonprofit institutions. The remaining 16 percent were either in the military or other organizations.

¹⁸NSF (1986b), back cover.

¹⁹See chapter 5, "Academic R&D and Basic Research: Patterns of Performance."

²⁰Hansen (1985), p. 6.

²¹NSF (1986a), p. 36.

²²NSF (1987b).

²³Ibid.

DEMOGRAPHIC TRENDS: EDUCATIONAL ATTAINMENT

Bachelor's and Master's Degrees

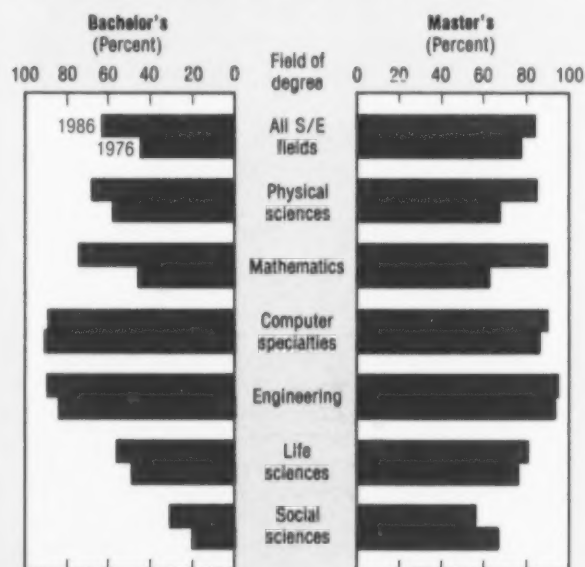
Partly in response to a perceived growth in employment opportunities, the number of college degrees awarded in engineering and computer science increased between 1976 and 1986. S/E graduates during this period benefited from higher employment rates. The proportion of bachelor's degree recipients employed in S/E occupations rose from 45 percent to 64 percent; S/E employment of master's degree recipients increased from 77 percent to 84 percent. (See figure 3-12.)

The strong demand for graduates in computer science, engineering, and mathematics was consistent with the high levels of employment in S/E occupations. Although there was substantial variation among fields, acquisition of a master's degree generally provided more S/E employment opportunities. While at least 90 percent of master's degree recipients in most major fields were employed in S/E occupations, the rates for life and social sciences were considerably lower—81 percent and 56 percent, respectively.²¹

In general, the S/E employment rates for men were higher than those for women at both the bachelor's and

²¹NSF (1988a).

Figure 3-12.
Percent of recent science/engineering (S/E) degree recipients employed in S/E jobs: 1976, 1986



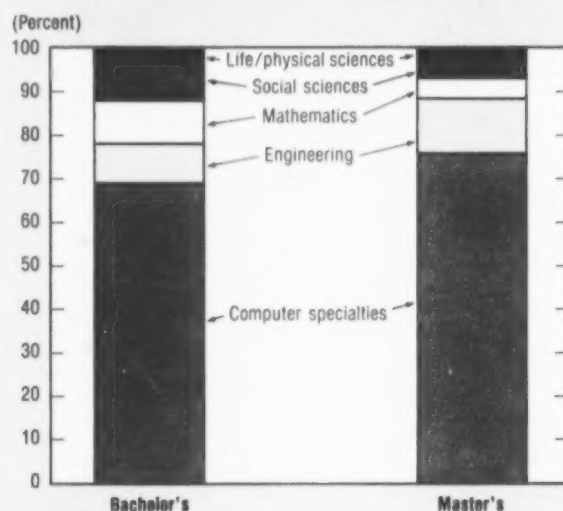
See appendix table 3-9.

Science & Engineering Indicators — 1987

master's degree levels. The concentrations of each sex in particular fields contributed to some of the difference in rates. For instance, the low S/E employment rate in the social sciences coupled with the concentration of women in these fields effectively lowered the average employment rate. Moreover, the high S/E employment rate in engineering—in which men were predominant—had the effect of raising men's average S/E employment rate.

The continuing high demand for computer specialists exceeded the supply of computer science majors and attracted graduates from other S/E fields, especially mathematics and engineering. In 1986, about four-fifths of both the bachelor's and master's degree recipients working as computer specialists were computer science graduates; this was an increase over 1984 levels, when about two-thirds of the bachelor's and master's degree recipients had computer science degrees. The rising share reflects the rapid increase in the number of degrees awarded in computer science. (See figure 3-13.)

Figure 3-13.
Degree field of 1984 and 1985 science/engineering graduates working as computer specialists in 1986



See appendix table 3-10.

Science & Engineering Indicators — 1987

Industry continued to be the major source of employment opportunities for new S/E graduates in 1986, providing jobs for 66 percent of those with bachelor's degrees and 66 percent of those with master's degrees. Educational institutions employed only 7 percent of the bachelor's and 15 percent of the master's, while the government sector (Federal, State, and local) accounted for between 12 and 16 percent of each group. Individuals with degrees (both levels) in the physical sciences, mathematics, engineering, and computer science were more

likely to be working in industry; recipients of degrees in other fields were more evenly distributed among the employment sectors.

Doctorates

In 1985, employed science and engineering doctorate holders in the United States numbered more than 400,000; this represented an increase of 82 percent since 1973. The proportion of S/E doctorate holders employed in non-S/E jobs increased steadily during this period, from 6 percent in 1973 to 8 percent in 1985.

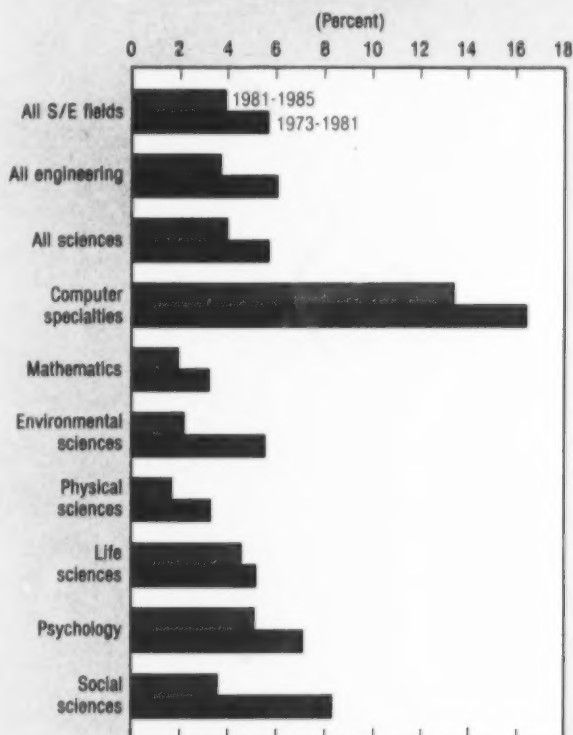
Increases in employment among doctoral scientists and engineers varied substantially among fields between 1973 and 1985. (See figure 3-14.) Employment of computer specialists increased by an average of 15.4 percent per year during this period; by contrast, overall employment of Ph.D. scientists and engineers increased at a rate of 5.1 percent. Physical and mathematical scientists showed much slower growth rates (2.8 percent per year each). Employment of social scientists increased by 6.7 percent per year, primarily because of rapid growth in a number of relatively small social science fields including—for example—communications, political science, and public policy and administration.

Employment growth of science and engineering doctorate holders has not been uniform. Engineering employ-

ment increased at a slightly faster rate than for scientists (6.0 percent versus 5.7 percent per year) between 1973 and 1981. Since 1981, however, employment growth in most S/E doctorate fields has slowed, with employment of Ph.D. scientists increasing at an average rate of 3.9 percent per year compared to 3.7 percent per year for doctoral engineers. (See figures 3-15 and 3-16.)

Figure 3-15.

Annual percentage growth of doctorates employed as scientists by field: 1973-1981 and 1981-1985

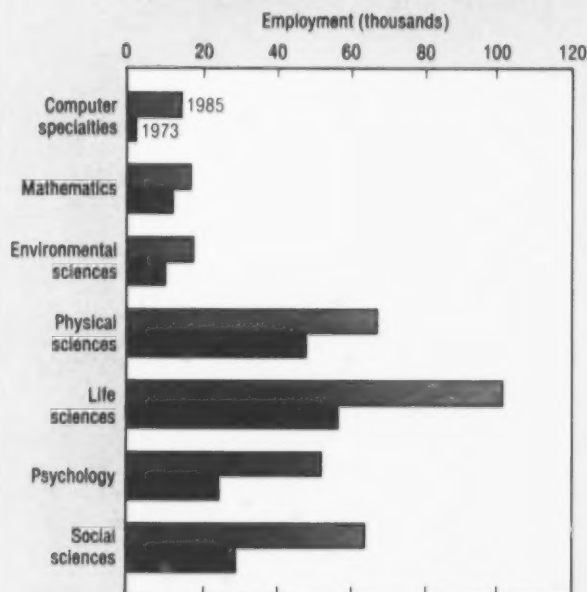


See appendix table 3-11.

Science & Engineering Indicators — 1987

Figure 3-14.

Doctorates employed in science, by field: 1973, 1985

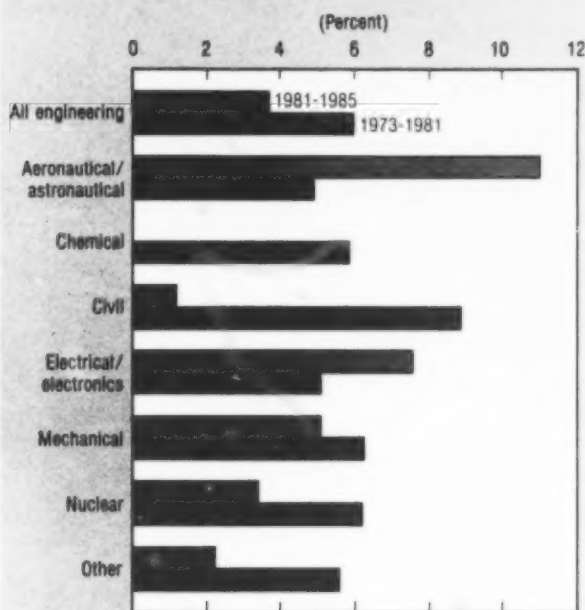


See appendix table 3-11.

Science & Engineering Indicators — 1987

A trend toward nonacademic employment of S/E doctorate holders began in the early 1970's. Between 1973 and 1985, employment of doctoral scientists and engineers in industry increased more than twice that in the other sectors—142 percent versus 64 percent. Employment of S/E doctorate holders in business and industry continued to increase sharply between 1981 and 1985, at an annual rate of 6.1 percent versus 2.9 percent for all other sectors combined. The educational sector—although continuing as the primary employer of doctoral scientists and engineers—showed an increase in doctoral S/E employment of only 3.2 percent per year between 1981 and 1985. The share of doctoral scientists and engi-

Figure 3-16.
Annual percentage growth of doctorates
employed as engineers by field: 1973-1981
and 1981-1985



See appendix table 3-11.

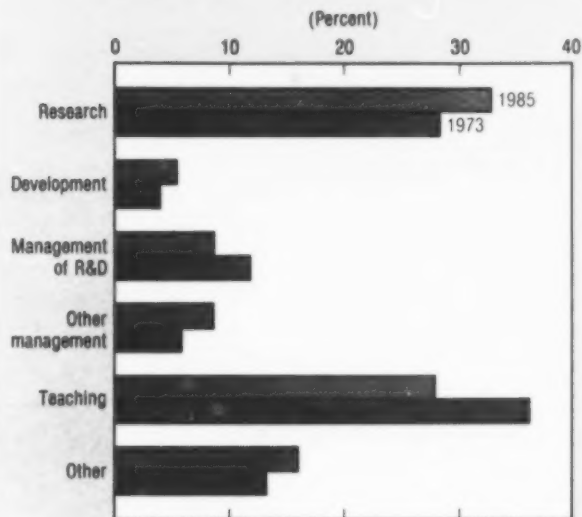
Science & Engineering Indicators — 1987

neers employed by business and industry, as compared with total employment of Ph.D. scientists and engineers, thus increased from 24 percent in 1973 to almost 32 percent in 1985. The slow growth rate of doctoral S/E employment in the academic sector during this period contributed to a reduction in its share of doctoral employment, from 59 percent in 1973 to less than 53 percent in 1985.

Between 1981 and 1985, industry employment of doctoral engineers increased at a slightly slower pace than in the academic sector (4.5 percent versus 4.8 percent per year), reversing the trends observed between 1973 and 1981. In contrast, Ph.D. scientist employment increased at an annual rate of more than 7 percent per year in industry between 1981 and 1985, but by only 3 percent per year in the academic sector.

The sectoral shifts in S/E Ph.D. employment between 1973 and 1985 were accompanied by a change in work activity patterns. During this period, for example, the proportion of doctoral scientists and engineers reporting teaching as their primary activity declined from 36 percent to 28 percent; this directly correlates to the shift to nonacademic employment. Management also declined in relative importance, decreasing from 21 percent to 17 percent. R&D activities remained stable, while a sharp increase occurred in activities related to such industrial applications as sales, production, and quality control.

Figure 3-17.
Work activities of employed doctoral scientists
and engineers: 1973 and 1985



See appendix table 3-12.

Science & Engineering Indicators — 1987

These activities accounted for 19 percent of the S/E doctoral workforce in 1985, up from 9 percent in 1973. (See figure 3-17.)

WOMEN IN SCIENCE AND ENGINEERING

Although women have made substantial gains in science and engineering employment over the last decade, they remained underrepresented in the S/E workforce in 1986. However, the 526,700 women scientists and engineers then employed represented about 13 percent of all scientists and engineers, up from 8 percent in 1976. On the other hand, women now constitute almost one-half of overall U.S. employment. These proportions reflect the fact that, historically, women's participation in pre-college science and mathematics courses and in undergraduate and graduate S/E education is below that of men. The underrepresentation of women varies between scientists and engineers: they accounted for almost 26 percent of scientists, but only 4 percent of engineers in 1986.

Although there has been dramatic growth in the employment of women scientists and engineers, they are still more likely than men to be both unemployed and underemployed. The unemployment rate for women scientists and engineers in 1986 (2.7 percent) was double the rate for men (1.3 percent). Women were also about three times as likely as men to report that they were underemployed (6 percent versus 2 percent); that is, working

part-time when full-time work is preferred, or working involuntarily in a non-S/E job.

Regardless of field, women scientists and engineers are less likely than men to be employed in industry or in the Federal Government. They are, however, more likely than men to work in State and local governments, nonprofit organizations, and academic institutions. Because of the more rapid increase in the employment of women, they are generally younger than their male colleagues and have fewer years of professional experience. In 1986, about three-fifths of the women and one-fourth of the men reported fewer than 10 years of professional experience.²⁵

Years of experience may affect several labor market variables. For example, women scientists and engineers in industry are less likely than men to hold management positions; in academia, they are less likely than men to hold tenure or be in tenure-track positions. However, women hold assistant professorships and nonfaculty positions more than twice as often as men—this is about the same proportion as in 1977.²⁶

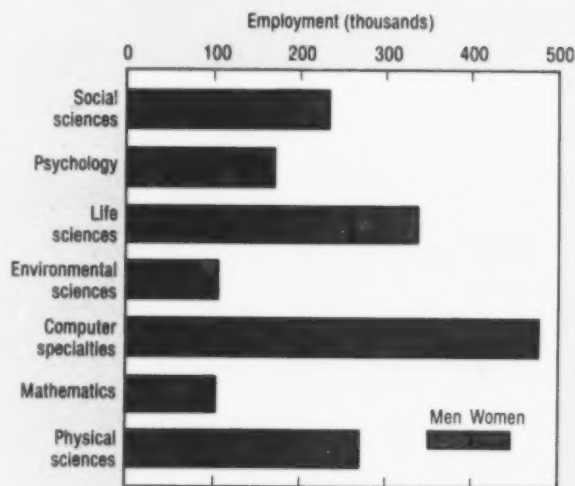
Women scientists and engineers also report salaries below those for men, with the smallest difference among those with less than 10 years' experience.²⁷ In fact, the average salaries earned by new S/E graduates are now about the same for both sexes in all fields.²⁸ The lower average salaries of women scientists and engineers with more than 10 years' work experience presumably reflect fewer opportunities for advancement.²⁹

Women's S/E participation varies considerably by field. For example, among scientists, women represented 42 percent of all psychologists in 1986, but only about 13 percent of physical and environmental scientists. (See figures O-12 in Overview and 3-18.)

Since the mid-1970's, however, the field distribution of employed women scientists and engineers has changed, reflecting differing growth patterns across S/E fields. The most notable changes were observed for computer specialists, engineers, and social scientists. Between 1976 and 1986, employment of women computer specialists increased more than sixfold (from 21,000 to 128,000); by 1986, 24 percent of women scientists and engineers were computer specialists, up from 12 percent in 1976. The number of women in engineering quadrupled, growing at an average annual rate of almost 16 percent per year; moreover, the proportion of women in S/E who are engineers rose from 11 percent to almost 18 percent. During the 1976-86 period, employment of women social scientists increased by 65 percent, much less than the overall growth of women in all S/E fields. As a result of this slow growth, the proportion who were social scientists declined from 31 percent to 18 percent. (See figure O-13 in Overview.)

Employment of doctoral women more than tripled between 1973 and 1985. The fields with the greatest relative growth of women doctorate holders were engineering—

Figure 3-18.
Employed scientists, by field
and gender: 1986



See appendix table 3-1.

Science & Engineering Indicators — 1987

in which employment of women increased from 100 in 1973 to 1,500 in 1985—and computer specialties—in which employment increased from 100 to 1,600 during the same period. Despite rapid growth in these fields, only about 5 to 6 percent of the women holding doctorates were computer specialists or engineers in 1985. More than 80 percent of the increase in the employment of women doctoral scientists and engineers took place in three major fields: life sciences, social sciences, and psychology. The field distribution of women with doctorates, however, did not change greatly over the 1973-85 period: women were somewhat more likely to be social scientists or computer specialists and less likely to be mathematical or physical scientists in 1985 than in 1973. (See figure 3-19.)

Despite the continuing disparity in academic rank, salary levels, and unemployment rates, women scientists and engineers have made important strides in increasing their participation at every degree level and in every field and employment sector. Moreover, an increasing proportion of precollege women are taking high school courses in science and mathematics that are essential in electing to pursue a science career.³⁰

The past 10 years have seen an especially dramatic increase in the number of women enrolling in and graduating from engineering schools. In 1983, women represented approximately one-fifth (17.0 percent) of the beginning engineering students nationally, as compared to 4.6 percent in the early 1970's.³¹ High school guidance

²⁵NSF (1988c).

²⁶Vetter (1987), p. 7.

²⁷NSF (1988c).

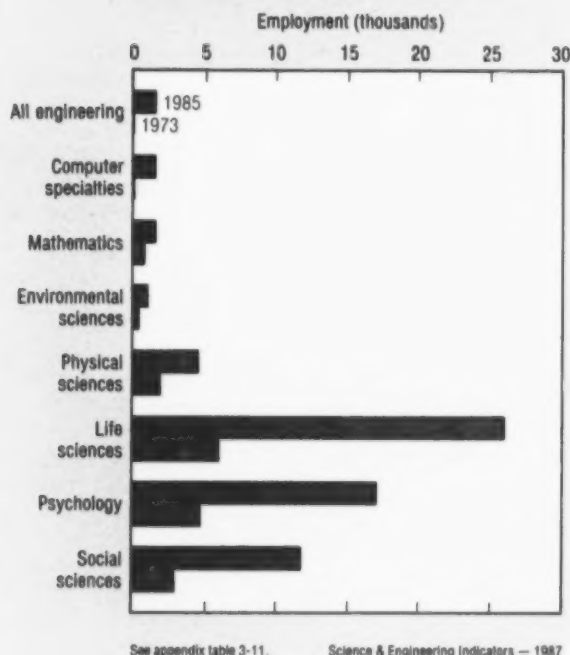
²⁸NSF (1988a).

²⁹NSF (1988c).

³⁰Vetter (1987), p. 8.

³¹Jagacinski and Lebold (1985), p. 204.

Figure 3-19.
**Women doctorates in science and
 engineering jobs by field: 1973 and 1985**



counselors today are much more likely to suggest an engineering career for a female student; the most popular career guidance instrument—the Strong-Campbell Interest Inventory—now includes among its career scales both male and female engineer scales. In addition, many colleges and universities sponsor programs to recruit talented female high school students for engineering careers.¹²

MINORITIES IN SCIENCE AND ENGINEERING

Over the last decade, minority groups in the United States have achieved substantial gains within the science and engineering workforce. The number of blacks, Asians, Hispanics, and native Americans employed as scientists and engineers has more than doubled since 1976, increasing faster than white S/E employment (110 percent versus 82 percent). Of the 363,000 minority scientists and engineers working in 1986, more than one-half (199,000) were Asian, while about 5 percent (18,700) were native American.¹³ Blacks and Hispanics¹⁴ represented about one-fourth (87,900 and 74,900) of the minority S/E workforce, respectively. (See figure O-14 in Overview.)

Blacks and Hispanics have historically been under-represented in the science and engineering workforce, while Asians have been strongly attracted to these careers and native Americans have held a proportionate share. In 1986, blacks accounted for only 2.5 percent of employed scientists and engineers. In contrast, they represented 10 percent of total U.S. employment and almost 6 percent of those employed in the professional and related workforce. Asians, on the other hand, represented less than 2 percent of the U.S. labor force, but almost 6 percent of all scientists and engineers. In the same year, Hispanics represented about 2.1 percent of employed scientists and engineers, while comprising 5.0 percent of all employed persons. Native American scientists and engineers represented somewhat less than 1 percent of total S/E employment; this was roughly equivalent to their participation in the overall U.S. labor force.

S/E field representation varied significantly among the racial/ethnic groups. Asians were the least likely to be employed in the environmental and behavioral sciences, while blacks were generally more likely to work as social scientists and life scientists. The proportions who were engineers in 1986 ranged from 42 percent of the blacks to 64 percent of the Asians. In comparison, 59 percent of the whites were engineers. Since 1976, blacks have moved away from engineering and toward the social sciences and computer specialties; among Asians, proportional increases have occurred in engineering and computer specialties.

Black and native American scientists and engineers were as likely as whites (29 percent) to hold management positions in 1986; in contrast, Asians (22 percent) and Hispanics (26 percent) were less likely to report management or administration as their primary work activity.^{15, 16} For those employed in educational institutions,¹⁷ both blacks and Asians were less likely than whites to hold tenure or be in tenure-track positions. Native Americans were more likely to hold tenure or be in tenure-track positions than were whites, and Hispanics were almost as likely as all scientists and engineers to hold tenure or be in tenure-track positions.

Salaries earned by black and Hispanic scientists and engineers in 1986,¹⁸ were, on average, below those earned by whites, Asians, and native Americans. While salaries for both Asians and native Americans were above those for their white colleagues in 1986, salaries for blacks averaged 81 percent of those for whites. Hispanics earned about 90 percent of the salaries paid across all racial/ethnic groups.

Generally, minorities in S/E are more likely than white scientists and engineers to be unemployed and under-employed, and less likely to work in S/E jobs.¹⁹ For example, while the unemployment rate for whites in 1986 was 1.5 percent, unemployment among black and Asian scientists and engineers averaged around 2.8 percent. Only

¹⁵Percentages include scientists and engineers employed in non-S/E activities.

¹⁶NSF (1988c).

¹⁷Ibid.

¹⁸Ibid.

¹⁹Ibid.

¹²Jagacinski, Linden, and Lebold (1985), p. 23.

¹³NSF (1988c).

¹⁴Includes members of all racial groups.

2.4 percent of the Asians reported that they were underemployed in 1986, compared to 2.5 percent of the whites; however, 5.5 percent of the blacks reported underemployment. The proportions of employed scientists and engineers working in S/E fields ranged from 79 percent of the native Americans to 77 percent of the blacks and 88 percent of the Asians.

While minority participation in the science and engineering workforce has risen steadily since 1976, increasingly greater numbers of S/E graduates from these groups may be required over the next decade.⁴⁰ While the general college-age population is predicted to decline in the 1990's, the proportion of blacks, Hispanics, Asians, and native Americans in the 18- to 24-year-old age group is expected to increase. The role of minority groups in the S/E workforce could thus expand significantly.

SUPPLY AND DEMAND FOR S/E PERSONNEL— LABOR MARKET INDICATORS

Demographic statistics on S/E employment trends alone do not indicate whether the current supply is sufficient to meet the economy's needs. Recent concerns over shortages of engineers and computer specialists and about suitable job opportunities for some scientists suggest a potential maldistribution in the S/E labor market and a need for indicators to assess supply and demand conditions. Standard labor market indicators of supply and demand conditions include labor force participation and unemployment rates. The S/E utilization rate also helps in assessing both the market for science and engineering jobs and the extent to which those with S/E training are utilizing their skills. While no single statistic can provide a firm basis for measuring shortages or surpluses of scientists and engineers, some statistics—when analyzed together—allow a meaningful inference about the S/E labor market condition.

Labor Force Participation Rates

The S/E labor force includes scientists and engineers who are employed—either in or outside of science and engineering—and those who are unemployed but seeking employment. In 1986, approximately 95 percent of the S/E population were in the labor force, with scientists and engineers equally likely to be working or seeking employment. Participation rates were about equal for men and women (95 percent versus 94 percent), with only a slight variation among major fields.

Unemployment Rates

A standard measure of labor market conditions is the unemployment rate, which measures the proportion of those in the workforce who are not employed but seeking work. In the last decade, scientists and engineers have been steadily improving their labor market position, outperforming both the general labor force and all professional and related workers. In 1976, the unemployment

rate for scientists and engineers was 3.0 percent compared to 3.2 percent for all professional and technical workers and 7.7 percent for the entire U.S. workforce. In 1986, these rates had fallen to 2.0 percent and 7.2 percent for all professional and technical workers and the total workforce. S/E unemployment fell at a faster rate, declining to 1.5 percent in 1986. (See figure 3-20.)

While almost all scientists and engineers who wanted jobs in 1986 were employed, the level of unemployment among the different S/E fields varied considerably. Environmental scientists posted the highest S/E unemployment rate at 4.4 percent; computer specialists experienced the lowest rate at 0.8 percent. Of engineering occupations, petroleum engineers showed the highest unemployment rate at 3.4 percent.

S/E Employment Rate

The S/E employment rate measures the extent to which employed scientists or engineers have a job in science or engineering. Depending on the specific reasons for non-S/E employment, a low S/E employment rate could be an indicator of underutilization. Factors relating to non-S/E employment include lack of available S/E jobs, higher pay for non-S/E employment, location, or preference for a job outside of science or engineering.

In 1986, the S/E employment rate was 85 percent (down slightly from 91 percent in 1976), with the rate for engineers (92 percent) substantially above that for scientists (77 percent). S/E employment rates ranged within science fields from 61 percent in the social sciences and 78 percent in the computer specialties, to 87 percent in the environmental and physical sciences. The relatively low S/E employment rate for computer specialists suggests that a substantial number may be applying their skills to commercial activities rather than to more traditional S/E activities such as research and development.

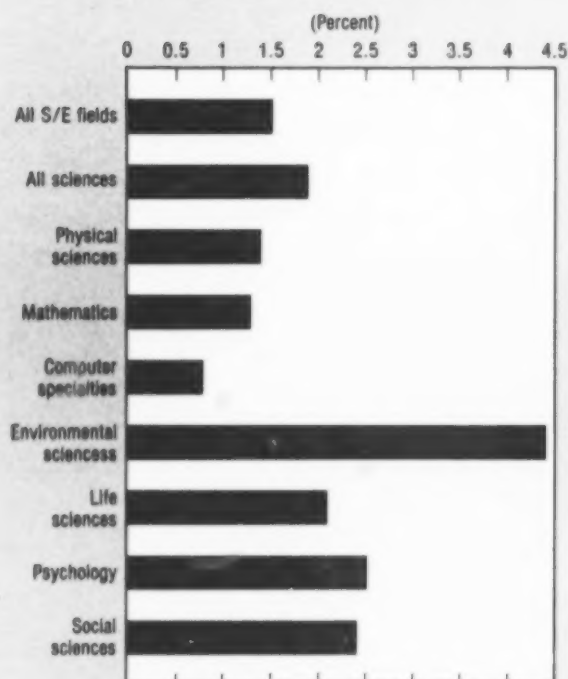
S/E Underemployment

Although unemployment rates of scientists and engineers are relatively low compared with rates for the general population, those who are employed may be underemployed. Working in a non-S/E job or working part-time may indicate underemployment, depending on the reasons for such employment. To help measure the extent of potential underemployment, the S/E underemployment rate was developed. This rate is defined as those who are involuntarily working in non-S/E jobs or involuntarily working part-time as a percent of total employment.

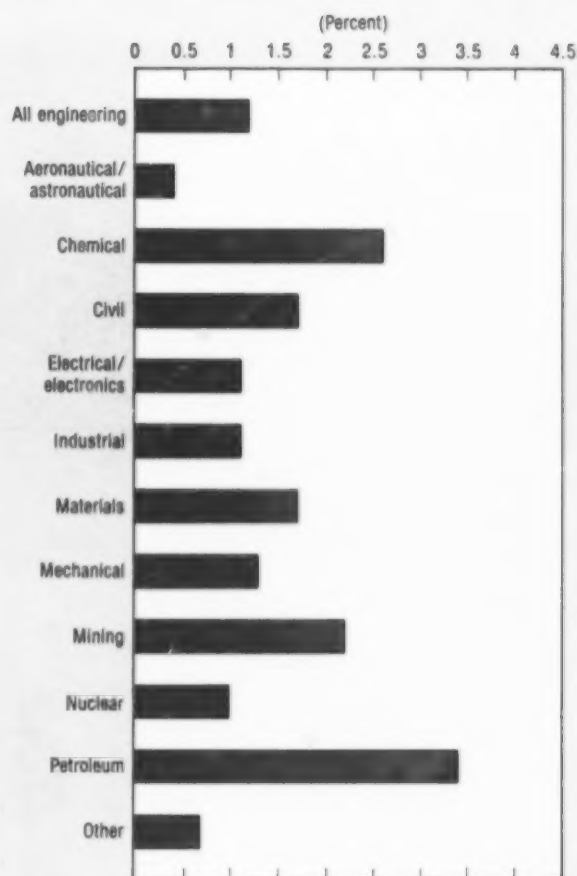
The underemployment rate for scientists and engineers in 1986 was 2.6 percent, with scientists much more likely than engineers to be underemployed (4.3 percent versus 1.0 percent). Among scientists, social scientists and psychologists (7.2 percent and 5.7 percent) are more likely than physical scientists and computer specialists (1.9 percent and 2.5 percent) to be underemployed. Underemployment among engineers ranged from 0.4 percent for nuclear engineers to 2.0 percent for mining engineers.

⁴⁰Finkbeiner (1987), p. 17.

Figure 3-20.
S/E unemployment rates by field: 1986



See appendix table 3-13.



Science & Engineering Indicators — 1987

S/E Underutilization

To derive a more comprehensive indicator of potential underutilization, figures for those who are unemployed and those who are underemployed may be combined and expressed as a percent of the labor force. In 1986, the derived underutilization rate for scientists and engineers was 4.1 percent. The rate for scientists (6.1 percent) was almost three times that for engineers (2.2 percent); among scientists, the highest underutilization rates were reported for environmental scientists and social scientists (roughly 10 percent each). Petroleum and chemical engineers posted the highest rates among engineering occupations, at about 5 percent each.⁴¹ (See figure 3-21.)

Shortages of S/E Personnel

Employer success in meeting staffing requirements is another direct indicator of S/E supply and demand labor

market imbalances. In 1985, relatively few industrial employers reported shortages of scientists and engineers. The only fields with as much as 15 percent of their employers reporting shortages were electronics engineering, nuclear engineering, and electrical engineering.⁴² This is in marked contrast to the labor market of 1981, when one-half or more of most engineering and computer specialties field employers reported shortages.⁴³

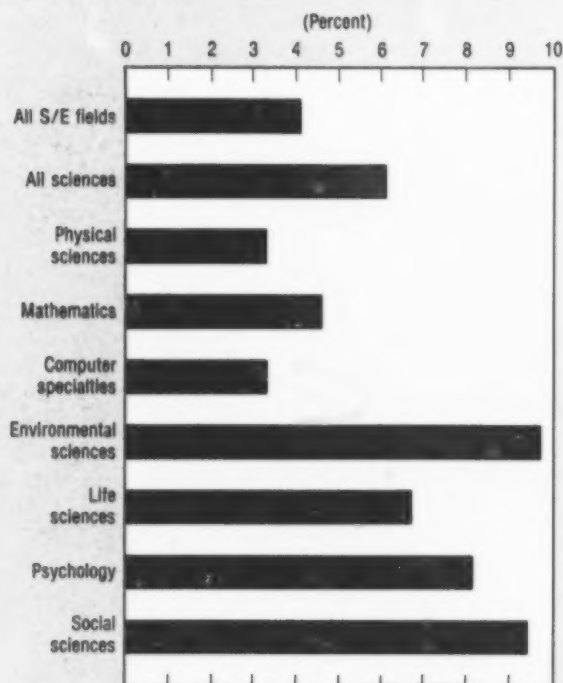
Engineering schools in the U.S. have reported what may be considered serious and persistent shortages of faculty. In 1986, almost 9 percent of authorized full-time engineering faculty positions were unfilled; moreover,

⁴¹The underutilization rate as derived here is only a partial measure, since it does not take into account the number of scientists and engineers who may have jobs requiring skills below those they actually possess.

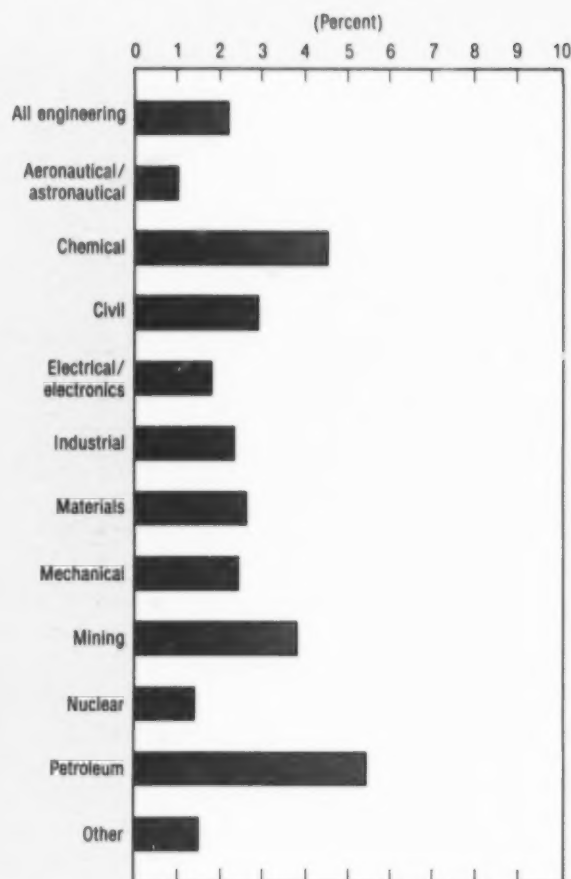
⁴²Market Facts, Inc. (1986), p. 3.

⁴³NSF (1982).

Figure 3-21.
S/E underutilization rates by field: 1986



See appendix table 3-13.



Science & Engineering Indicators — 1987

many institutions stated that the authorized levels would be higher if it were possible to fill such positions.⁴⁴ Engineering faculty shortages are grounded in the long-term decline in engineering doctorates awarded to U.S. citizens (see the discussion below on the S/E pipeline) and increasing demand for engineering Ph.D. holders in the industrial sector. (See the previous section on doctorates.)

Overview

The employment indicators discussed above suggest that the labor market situation for scientists and engineers has been favorable. It can, for example, be inferred from the relatively high S/E participation rates and low S/E unemployment rates that in 1986 there was generally

sufficient demand to accommodate the S/E labor force. In addition, the low levels of shortages reported by industrial employers in 1985 would indicate that the S/E labor force is in general—with the single exception of engineering Ph.D.'s—nearly sufficient to meet the economy's current demands. For now, there appears to be a rough balance between supply and demand for science and engineering personnel.

The positive balance between supply and demand for S/E personnel has been accomplished, however, through means other than new S/E graduates with fully appropriate training in their occupational fields. Substantial occupational mobility (with attendant possible quality costs⁴⁵) and increasing reliance on foreign-origin personnel (native-born U.S. citizens declined from 90 percent of the S/E labor force in 1972 to 83 percent in 1982⁴⁶) have

⁴⁴NSF (1988b).

⁴⁵Dauffenbach and Finn (1984).

⁴⁶NSF (1986a), p. 39.

been largely responsible for the supply/demand equilibrium in the science and engineering labor market.

PROJECTED DEMAND

Short-Term Outlook

Overall 1986 labor market conditions for scientists and engineers indicate favorable job prospects for the remainder of the 1980's; however, recent events, as outlined below, may severely affect the number of anticipated employment opportunities in certain fields and industries.

The drastic drop in the price of crude oil to under \$10 a barrel in 1986—and the subsequent closing of numerous oil refineries and related production facilities—has had a profound effect on petroleum-related S/E employment. In 1982, nearly 7,000 students at four major southwest universities—University of Oklahoma, Texas A&M University, University of Texas, and Louisiana State University—were pursuing studies in petroleum engineering, geology, and geophysics. Since that time, however, the number of students majoring in these fields has declined annually.⁴⁷ Professors at each school have expressed concern that the fall of 1986 will mirror the fall of 1982—and that, just as the supply of graduates in 1986 exceeds demand, too few will graduate in 1990 to meet what many experts predict will be heightened demand 4 years hence.⁴⁸

Electrical/electronics graduates are also expected to experience short-term difficulty in finding employment with high-tech companies.⁴⁹ Between 1985 and 1986, the electronics industry recorded a 3.4-percent drop in total employment, representing a decline of about 75,000 jobs during the year.⁵⁰ Component companies, particularly hit hard in 1986, lost 33,000 jobs or 5.0 percent of their workforce; computer manufacturers saw their employment ranks dwindle by 7.4 percent to 418,000. On the other end of the spectrum, however, the software/programming sector recorded sizable gains in employment, up 20,500 jobs (a 10.4-percent increase) between 1985 and 1986.

Engineering students in 1987 were expected to find fewer jobs and less opportunity when they graduated. Between July 1986 and July 1987, the College Placement Council reported a significant drop in the number of offers to new bachelor's degree recipients in engineering.⁵¹ In addition, a recent poll of 761 employers found a slight tapering off in overall demand. However, the outlook for computer science, mathematical science, and electrical/electronics engineering graduates was still the highest in terms of supply/demand ratios.⁵²

Long-Term Outlook

Looking ahead to the year 2000, high-technology industry growth and the increasing use of high-technology goods and services in the economy as a whole will lead to the increasing employment of science, engineering, and technical personnel in industry.⁵³ The Bureau of Labor Statistics (BLS) estimates that the net increase in all new jobs (technical and nontechnical combined) created between 1986 and 2000 will be in service-producing industries. Goods-producing industries, in contrast, are projected to show virtually no net change in overall employment levels, as projected increases in construction will be offset by employment declines in mining and manufacturing.

The computer and data processing industry is projected to be the fastest growing of all industries in the economy,⁵⁴ providing the greatest number of employment opportunities for science, engineering, and technical personnel. Underlying this development are the continued shift toward contracting out various firm operations and the growth in demand for computer software and other types of modern business services. Most of the growth within this industry is likely to occur in programming and software services. The investment boom in high-technology products such as computer-aided design/computer-aided manufacturing (CAD/CAM) and robotic production techniques projected to occur in the 1990's⁵⁵ will require significant increases in new software development, especially in high-level programming languages.

While overall employment growth is expected to decline within the manufacturing sector through the end of the century, the changes in workforce composition that occurred over the previous decade are expected to continue into the 1990's. Although projected to show only moderate employment increases, the computer production and semiconductor industries are nevertheless predicted to be among the leaders in output growth through the 1990's, increasing at 7.4 and 5.8 percent⁵⁶ per year, respectively, compared to only 2.4 percent annually for GNP.⁵⁷ This expected growth will necessitate an increasingly greater emphasis on "knowledge" skills, with the proportion of labor-intensive workers continuing to decline.

College and university faculty are expected to decline overall in the 1990's in response to an expected decrease in total college enrollments; this in turn will stem from a drop in the traditional college-age population. This decline, in addition to expected low retirements of current faculty,⁵⁸ may adversely affect academic job prospects in the near future for scientists. Possible increases in the proportions of college students enrolling in science programs could alleviate this situation. (See discussion on supply, below.) On the other hand, engineering faculty

⁴⁷Commission on Professionals in Science and Technology (1986), p. 4.

⁴⁸Ibid.

⁴⁹American Electronics Association, as reported in Commission on Professionals in Science and Technology (1986), p. 5.

⁵⁰U.S. Department of Labor, Bureau of Labor Statistics (1987), pp. 68, 77, 203.

⁵¹College Placement Council Salary Survey (1987).

⁵²Shingleton and Scheetz (1986), p. 15.

⁵³Silvestri and Lukaszewicz (1987), p. 47.

⁵⁴Personick (1987), p. 39.

⁵⁵Ibid.

⁵⁶Ibid., p. 34.

⁵⁷Kutscher (1987), p. 4.

⁵⁸Finn (1986).

shortages have been persistent, primarily because of a notable drop (compared to the 1970's) in the number of American citizens who obtained Ph.D.'s in engineering, and an increasing proportion of Ph.D. engineers opting for employment in private industry.

The employment opportunities for scientists, engineers, and technicians are projected to increase substantially between 1986 and 2000, rising by approximately 36 percent, compared to 19 percent for all occupations. This growth will vary dramatically among fields, however; computer specialists are expected to experience the largest employment increase and drafters the smallest. (See table 3-1.)

Table 3-1. Projected increase in demand between 1986 and 2000 for scientists, engineers and technicians (SET's), by field

Field	Percent
Total SET fields	36
Total scientists	45
Computer specialists	76
Life	21
Mathematical	29
Physical	13
Social	36
Total engineers	32
Aeronautical/astronautical	11
Chemical	15
Civil	25
Electrical/electronics	48
Industrial	30
Mechanical	33
Other	24
Total technicians	36
Computer programmers	70
Drafters	2
Electrical/electronics	46
Other engineering	26
Physical, mathematical and life sciences	15

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, *BLS Monthly Labor Review* (September 1987), pp. 51-52

Science & Engineering Indicators—1987

Engineering employment is expected to increase 32 percent between 1986 and 2000. Much of this increase will occur among electrical/electronics engineers engaged in developing computers, communications equipment, and defense-related electronic equipment. Mechanical and civil engineering employment are also expected to grow rapidly during this period. Mechanical engineers will be needed to keep product design and production methods up to date in support of industry's desire to remain competitive. Civil engineers will be needed for additional heavy construction.

Among science occupations, employment of mathematical scientists is projected to grow by 29 percent be-

tween 1986 and 2000, primarily because of increased statistical work and mathematical modeling. Chemists, on the other hand, are expected to increase by only 11 percent, reflecting the massive corporate restructuring of the chemicals industry in 1984-85.¹⁰

As stated above, the highest employment growth among all S/E occupations is projected to be in computer specialties. The continued expansion of computer and data processing-related services industries will be accompanied by an increasingly greater demand for computer specialty skills; the number of computer specialists engaged in developing and operating computer-based systems is projected to increase by 76 percent between 1986 and 2000.

S/E technicians are projected to increase 23 percent between 1986 and 2000 in direct correlation to the employment trends of corresponding science and engineering occupations. (See table 3-1.) Computer programmers are expected to increase by 70 percent during this period, keeping pace with computer specialists. However, different rates of change are expected for the various other specialties, given the changing demographics of the college-age population and other factors affecting employment rate growth/decline within the education sector.

S/E SUPPLY OUTLOOK

The S/E Pipeline

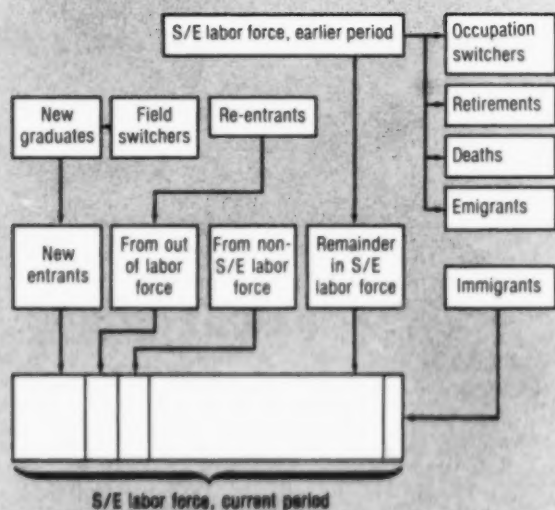
The flows of S/E workers in and out of the labor force generally serve as equilibrating marketplace forces bringing supply and demand into balance. Such flows signal future supply conditions for use by persons making career plans, handling recruiting activities, planning academic programs, or developing Federal policies on science and technology. There are three direct sources of flows into and out of the science and engineering workforce—new graduate entrants, occupational mobility, and separations from the labor force. The bulk of supply changes in the S/E labor market are formed by these movements. (See figure 3-22.)

New Entrants. New S/E graduates at the bachelor's, master's, and doctorate degree levels provide the basic inflow into the science and engineering workforce. However, the number earning S/E degrees—especially at the undergraduate level—is not identical to the supply of new S/E workers. For instance, new S/E bachelor's recipients may choose to pursue graduate education, which may be a prerequisite for employment in some fields, rather than immediately enter the labor force. In addition, some S/E baccalaureates may enter non-S/E occupations, or may work part-time while pursuing graduate education on a part-time basis.

In 1986, about 20 percent of recent S/E bachelor's degree recipients were enrolled in full-time graduate studies while an additional 11 percent were enrolled on a part-time basis; corresponding rates of 21 percent and 9 percent were observed among master's degree recip-

¹⁰American Chemical Society (1986), p. 23.

Figure 3-22.
S/E labor market flows



Note: The sizes of the boxes do not represent actual values.
Science & Engineering Indicators - 1987

ients.⁶⁰ Analysis by field shows that labor force demand inversely affected graduate school enrollment rates. For example, relatively low full-time enrollment rates of 5 percent to 17 percent were observed in such high-demand fields as engineering, mathematics, and computer science; rates of 21 percent to 39 percent were observed in fields showing lower demand, such as the social sciences and physical sciences.

Occupational Mobility. Experienced workers constitute the second category of personnel affecting overall S/E supply. These workers provide a short-term flexibility to the S/E supply system that cannot be met through recent college graduates. The mobility of these workers is determined primarily by job opportunities across various occupations as well as by occupation-specific characteristics.

The ability of the S/E labor market to respond to unanticipated surges in demand was severely tested over the last decade by the semiconductor and computer industries. The initial increase in requirements for people trained in engineering and computer science far exceeded the expected number of new graduates in these fields. For a short-term remedy, employers relied on the successful importation of scientific and technical talent from related fields.⁶¹ The long-term response to the continuing demand has been increased employer training of current engineering⁶² and computer personnel as well as a rise in the number of new S/E graduates in these fields.

⁶⁰NSF (1988a).

⁶¹U.S. Congress, Office of Technology Assessment (1985), p. 6.

⁶²Dauffenbach and Finn (1984).

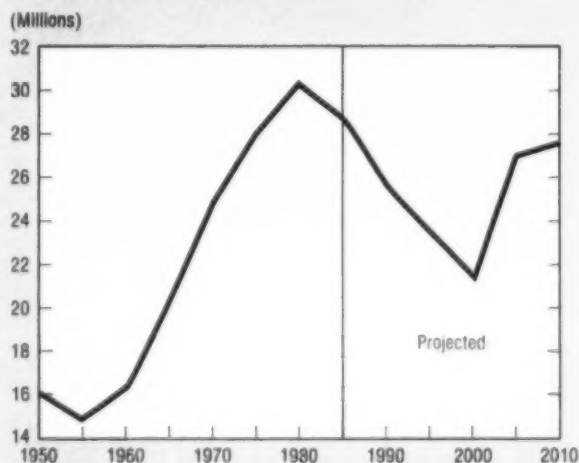
Separations. The available supply of S/E personnel is reduced by deaths and retirements. While separation rates depend partially on age distribution and life expectancy, potentially more immediate and significant effects on attrition could come from changes in the length of time people choose to remain in the S/E labor force. Such economic conditions as rising inflation rates (affecting a pension's purchasing power) and the abolishment of compulsory retirement policies are only two of the factors that could lead to postponing retirement. It is difficult to assess the net effect of these factors on future S/E separation rates.

Outlook

In the 1990's, changing demographics may impose restraints on the supply of newly trained scientists and engineers. The smaller birth cohorts of the early 1970's will definitely reduce the size of the traditional college-age population and could possibly reduce college enrollments. In fact, with the population of 18- to 24-year-olds expected to decline by 23 percent between 1980 and 1995⁶³ (see figure 3-23) college enrollments could decrease by as much as 12 to 16 percent by 1995.⁶⁴ Additionally, the first waves of the baby boom population that entered the labor force in the 1960's will begin to retire. These two combined forces may hinder workforce ability to meet demand increases over the next decade.

On the other hand, a declining college-age population does not necessarily mean a corresponding decline in the

Figure 3-23.
18-24 year olds in the U.S. population, 1950-2010



See appendix table 3-14.

Science & Engineering Indicators - 1987

number of new S/E entrants to the labor force. The enrollment gap may be filled to a certain extent by increased participation of older students and foreigners; many of these latter remain in the U.S. to work. Also, small shifts in the percentages of students choosing to train in S/E fields and of graduates who choose to enter S/E employment fields could change limited supplies of new entrants into considerably larger numbers; these shifts would thus eliminate labor market shortages of scientists and engineers.⁶⁵ Similar upward adjustments in the proportion of college students enrolling in science and engineering could also affect the demand for S/E doctorate holders to fill faculty positions.

The magnitude of these possible adjustments is uncertain. Past experience would indicate that the labor markets have sufficient flexibility to respond; however, forward projections are much more problematic. For example, although it is known that older students are a rising proportion of all undergraduates, it is uncertain how many of them will enter S/E employment fields. Also, while it is believed that adjustments in enrollment patterns will be made in response to a growing demand for S/E graduates, it is not clear that such adjustments will be sufficient to provide an adequate supply.

There are other adjustments that could occur. Labor force mobility is particularly important in tight market situations where both newly trained S/E entrants and experienced S/E personnel may be induced to leave their current fields of specialization and transfer into higher demand fields. (This is what occurred to satisfy the very high growth in demand for computer specialists.) There may also be delays in S/E worker retirements in response to needs for their services; this has been the case in past serious engineering shortages. Employers may also provide training and upgrading of technician personnel.

Widespread postponement of retirements and promotion of technicians into professional positions could, however, adversely affect the quality and caliber of the S/E workforce. In academia, the "graying" of faculty and the inability of universities and colleges to recruit and hire new Ph.D. graduates may combine to create a less productive and non-research-oriented scientific academic community.⁶⁶ In industry, employer-trained technicians placed in professional positions will not provide the same degree of technical ability or occupational mobility as academically trained S/E personnel.⁶⁷

INTERNATIONAL EMPLOYMENT OF SCIENTISTS AND ENGINEERS

The employment of scientists and engineers is a significant indicator of the level of effort and relative national priorities for science and technology among major industrial countries. While there are always problems of international comparability given differences in data collection methods and data estimation, these employment

data provide meaningful insight into the relative strengths of the S/E workforces of the United States and other countries.

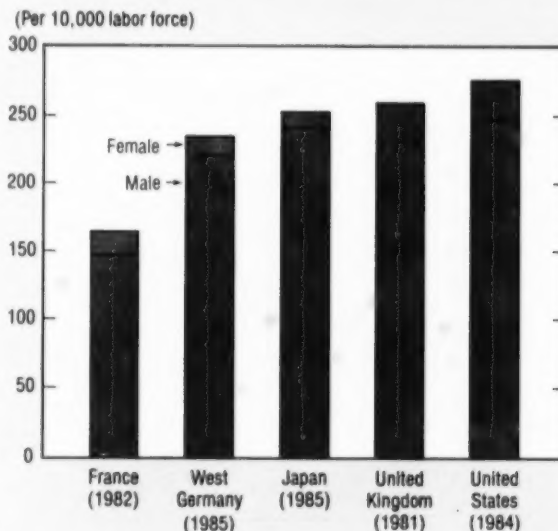
In the early 1980's, the number of nonacademic scientists and engineers employed in the U.S. was about equal to the combined total of those in France, West Germany, Japan, and the United Kingdom. This result was not unexpected, however, because the total U.S. population is about the same as that of the other countries combined. When the number of scientists and engineers as a proportion of the total labor force is examined for each country, however, the outcome is somewhat different. Here, the United Kingdom, Japan, and the United States employed almost the same percentage of scientists and engineers, with the United States employing slightly more than the others. (See figure 3-24.)

In all countries examined, service industries employed the largest proportion of scientists, while manufacturing industries predominated among employers of engineers.

In the United States and Japan, one-quarter of the scientists and engineers employed in manufacturing industries in the early 1980's were electrical/electronics engineers. Manufacturing industries in West Germany and France employed relatively more civil engineers than in the other countries, while the United Kingdom employed a relatively greater proportion of natural scientists. Japan had a much higher proportion of its scientists and engineers employed in service and construction industries, while U.S. scientists and engineers were more evenly divided between manufacturing/mining indus-

Figure 3-24.

Non-academic scientists and engineers per 10,000 total labor force, for selected countries, by gender



See appendix table 3-15.

Science & Engineering Indicators — 1987

⁶⁵Hansen (1986).

⁶⁶Paula Stephan, as reported in Cunningham (1986), p. 6.

⁶⁷Dauffenbach and Finn (1984).

tries and service industries. In France, a very high percentage of S/E's worked in the government sector. (See figures 3-25 and 3-26.)

The United States has the largest number—both in absolute terms and as a proportion of the labor force—of scientists and engineers working in R&D of any country except the Soviet Union. (See figures 3-27 and O-7 in Overview.) Other countries have, however, been closing the gap and now have concentrations of R&D scientists and engineers approximating that of the United States. In 1985, Japan's ratio per 10,000 (63.2) was very close to that of the U.S. (67.4).

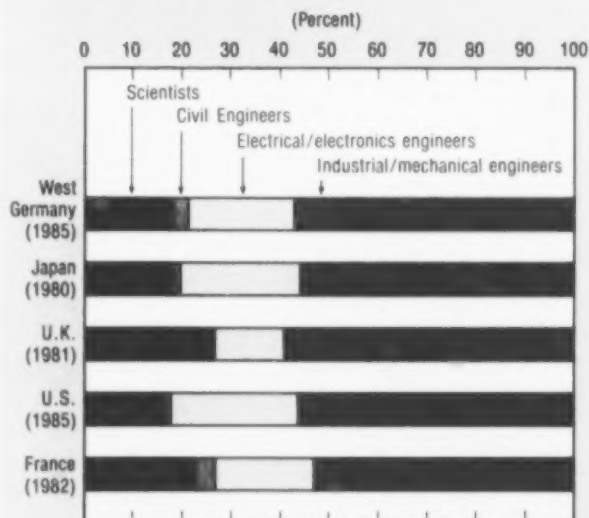
The United States was second to the United Kingdom in the number of scientists per 10,000 total labor force (101 versus 113 per 10,000) and third to West Germany in the number of engineers per 10,000 labor force (175 versus 194 per 10,000) in the mid-1980's. However, the U.S. ranked first among the countries compared in both the ratio of scientists and of engineers with university degrees.⁶⁶ In West Germany, most engineers have qualifications from technical colleges.⁶⁷ Of the reported S/E's in the United Kingdom, less than one-half has a university degree. Nonetheless, some of these countries may have stronger training in science and mathematics at the pre-college level than has the U.S.

The United Kingdom, France, and West Germany all had greater concentration of first university degrees in the natural sciences in 1984/85 than did the United States. (See figure O-8 in Overview.) In absolute numbers, however, there were more U.S. degree recipients. In 1982, Japan graduated more engineers at the bachelor's degree level than did the U.S.; by 1985, however, the number of U.S. engineering graduates was 9 percent greater because of an increase in the number of U.S. graduates and a decline in Japanese engineering degrees. The U.S. awards more than twice the number of engineering doctoral degrees and almost 10 times the number of natural science doctorates than does Japan.

The age of a country's S/E labor force can be an indicator of training recency and future capabilities. On average, women scientists and engineers were younger than their male counterparts in all countries. Japan had the youngest scientists and engineers of all five countries. In 1985, almost 50 percent of Japanese nonacademic scientists and engineers were under 35 years old, and only 7 percent were 55 or older. This supports recent observations on the high output of the Japanese educational system. Scientists and engineers, on average, had a higher median age in France than in the other countries. (See figure 3-28.)

When all five countries were compared, the vast majority of engineers were men, with the small proportion of females slowly increasing. Science occupations were also predominantly male, but with a larger percentage of

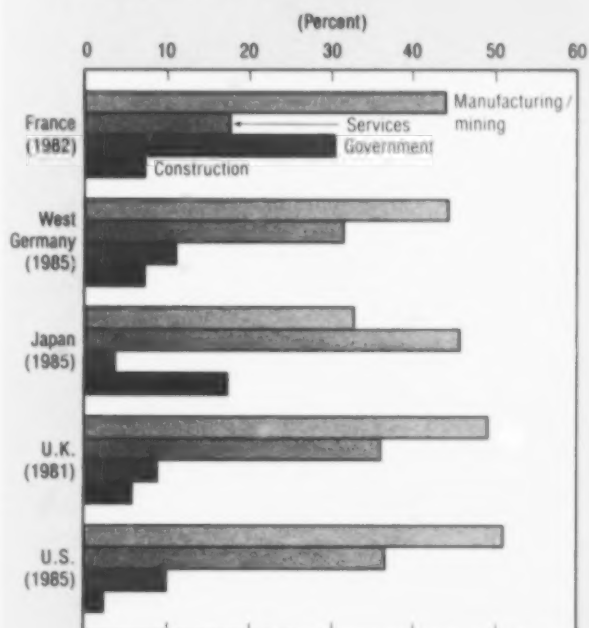
Figure 3-25.
Distribution of scientists and engineers
in manufacturing for selected countries,
by occupation group



See appendix table 3-16.

Science & Engineering Indicators — 1987

Figure 3-26.
Distribution of scientists and engineers
for selected countries, by sector



See appendix table 3-18.

Science & Engineering Indicators — 1987

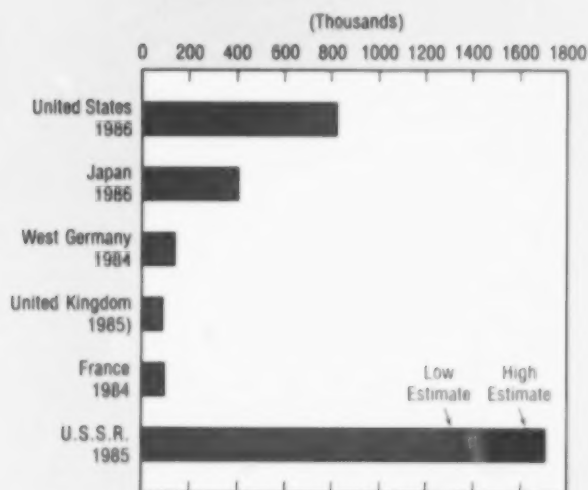
⁶⁶Way and Jamison (1986), p. 2.

⁶⁷For purposes of comparability, only engineers with university degrees are used. West German engineers trained in professional colleges generally have received more specialized and technically intensive training, while university degree recipients have received broader and more academic engineering training.

women represented. The United States and the United Kingdom had the best records for utilizing female scientists and engineers; only 6 percent of scientists and engineers in West Germany were women, and nearly one-half of these were social scientists. In Japan, engineers

outnumbered scientists by almost 4 to 1. Women comprised only 5 percent of Japan's scientists and engineers; nearly one-half of these were computer specialists. In the United Kingdom, 4 out of 10 male scientists and engineers were industrial or mechanical engineers, the same proportion as in West Germany.

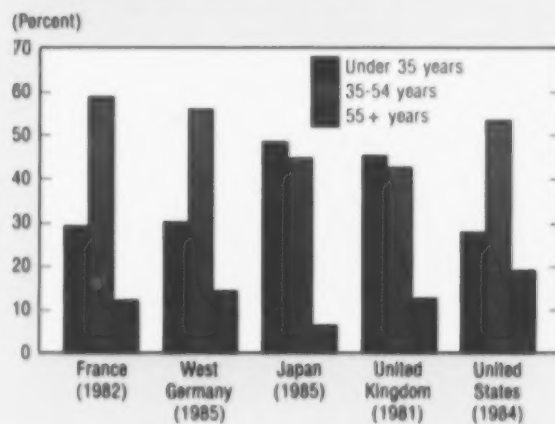
Figure 3-27.
Scientists and engineers engaged in R&D for
selected countries



See appendix table 3-19.

Science & Engineering Indicators — 1987

Figure 3-28.
Distribution of scientists and engineers
for selected countries, by age group



See appendix table 3-20.

Science & Engineering Indicators — 1987

REFERENCES

American Chemical Society, "Unemployment Slightly Higher for Chemists in the Past Year," *Chemical and Engineering News*, June 30, 1986.

Bowen, W., *Report of the President* (Princeton: Princeton University, April 1981).

College Placement Council Salary Survey, *Formal Report No. 3, July 1987* (Bethlehem, PA: College Placement Council, 1987).

Commission on Professionals in Science and Technology, *Manpower Comments*, Vol. 23, No. 6, July-August 1986.

Council of Economic Advisors, *Economic Report of the President* (Washington, DC: 1987).

Cunningham, R.T., "The Relationship between Age, Vintage and the Productivity of Scientists," *Research*, Georgia State University, Spring 1986.

Dauffenbach, R.C. and M.G. Finn, *Issue of Quality in the Engineering Work Force* (Oak Ridge, TN: Oak Ridge Associated Universities, December 1984).

Doigan, P., "ASEE Survey of Engineering Faculty and Graduate Students, Fall 1983," *Engineering Education* (October 1984).

Drucker, P.F., "The Changed World Economy," *Foreign Affairs*, Vol. 64, No. 4, 1986.

Finkbeiner, A.K., "Demographics or Market Forces?," *Mosaic*, NSF 86-88, Vol. 18, No. 1, Spring 1987.

Finn, M.G., *Factors Affecting the Demand for Natural Scientists and Engineers in the United States, 1985-2010: A Review of Existing Knowledge* (Oak Ridge, TN: Oak Ridge Associated Universities, July 1986).

Hansen, W.L., "Salary Differences across Disciplines," *Academe*, July-August 1985.

Hansen, W.L., "The Impact of Demographic Trends on the Scientific and Engineering Work Force," testimony presented before the Science Policy Task Force, Committee on Science and Technology, U.S. House of Representatives, February 27, 1986.

Jagacinski, C.M., K.W. Linden, and W.K. LeBold, "Today's Women in Engineering," *U.S. Women Engineers*, July/August 1985.

Jagacinski, C.M. and W.K. LeBold, "Comparisons of Women and Men in the Engineering Workforce," *IEEE Transactions on Education*, Vol. E-28, No. 4, November 1985.

Kutscher, R.E., "Overview and implications of the projections to 2000," *Monthly Labor Review*, U.S. Department of Labor, Bureau of Labor Statistics, Vol. 110, No. 9, September 1987.

Market Facts, Inc., *1985 NSF Science and Engineering Labor Market Study* (Washington DC: April 1986).

National Research Council, Commission on Human Resources, *Research Excellence through the Year 2000: The Importance of Maintaining a Flow of New Faculty into Academic Research* (Washington, DC: 1979).

National Science Foundation, "A decade's shift in industry science and engineering job patterns," *Mosaic*, NSF 87-34, Vol. 18, No. 3, Fall 1987a.

National Science Foundation, *Characteristics of Recent Science/Engineering Graduates: 1986* (Washington, DC: National Science Foundation, 1988a).

National Science Foundation, "Federal Scientists and Engineers: 1986," *Science Resources Studies* detailed tables (Washington, DC: National Science Foundation, 1987b).

National Science Foundation, *Foreign Citizens in U.S. Science and Engineering: History, Status, and Outlook*, NSF 86-305 (revised) (Washington, DC: National Science Foundation, 1986a).

National Science Foundation, "Labor Markets for New Science and Engineering Graduates in Private Industry," *Science Resources Studies Highlights*, NSF 82-310 (Washington, DC: National Science Foundation, 1982).

National Science Foundation, "Shortages Persist for Some Engineering Fields in Industry," *Mosaic*, NSF 86-15, Vol. 17, No. 2, Summer 1986b.

National Science Foundation, *Women and Minorities in Science and Engineering*, NSF 88-301 (Washington, DC: National Science Foundation, January 1988c).

National Science Foundation, *Young and Senior Science and Engineering Faculty and Nonfaculty Research Doctorates: 1986* (Washington, DC: National Science Foundation, 1988b).

Personick, V.A., "Industry output and employment through the end of the century," *Monthly Labor Review*, U.S. Department of Labor, Bureau of Labor Statistics, Vol. 110, No. 9, September 1987.

Shingleton, J.D. and L.P. Scheetz, *Recruiting Trends 1986-87* (Michigan State University, December 1986).

Silvestri, G.T. and J.M. Lukasiewicz, "A look at occupational employment trends to the year 2000," *Monthly Labor Review*, U.S. Department of Labor, Bureau of Labor Statistics, Vol. 110, No. 9, September 1987.

U.S. Congress, Office of Technology Assessment, *Demographic Trends and the Scientific and Engineering Work Force, A Technical Memorandum* (Washington, DC: December 1985).

U.S. Department of Labor, Bureau of Labor Statistics, *Supplement to Employment and Earnings* (Washington, DC: U.S. Department of Labor, July 1987).

Vetter, B. "Women's Progress," *Mosaic*, NSF 86-88, Vol. 18, No. 1, Spring 1987.

Way, P.O. and E. Jamison, *Scientists and Engineers in Industrialized Countries* (Washington, DC: U.S. Bureau of the Census, Center for International Research, November 1986).

Zampelli, E.M., "Growth, Structural Change, and the Employment of Scientists and Engineers, 1972-1982," (Washington, DC: Catholic University of America, July 1986).

Chapter 4

Resources for R&D and Basic Research

Resources for R&D and Basic Research

HIGHLIGHTS

- *Strong recent growth in U.S. research and development (R&D) spending has kept it ahead of that of other Western industrialized nations. The U.S. spends more on R&D than the next four largest Western industrialized countries combined and devotes the highest percentage of its gross national product (GNP) to R&D (2.8 percent in 1987, the highest rate since 1968). Federal spending on defense R&D is the biggest component of recent growth. (See p. 77.)*
- *If only nondefense R&D spending is considered, West Germany and Japan have outpaced U.S. R&D spending for 15 years, and their rates of investment in civilian R&D as a percentage of GNP have been rising faster than the U.S. rate for the past 5 years. (See p. 77.)*
- *Over the past decade, U.S. expenditures for both total R&D and basic research have grown faster than GNP. Total R&D grew by 5.9 percent between 1985 and 1986, basic research by 5.4 percent in constant dollars. (See pp. 2, 77, 241.)*
- *Federal agencies provided 63 percent of the total support for academic R&D in 1987, down from 68 percent in 1980. Industry support for academic R&D grew from 4 percent in 1980 to 6 percent in 1987. (See p. 78.)*
- *The Nation is currently experiencing an upsurge of capital spending for academic science and engineering (S/E), although the long-term trend in constant dollars is down. In 1985, Federal sources provided 11 percent of the total support for academic capital facilities for science and engineering—their lowest percentage for more than 2 decades. State Governments provided 40 percent of the support for new construction of capital facilities in 1985-86, and funds from tax-exempt bonds contributed another 30 percent. (See p. 80.)*
- *Current fund expenditures for research equipment at universities and colleges rose by 17 percent between 1985 and 1986. From 1980 to 1986, expenditures in this area more than doubled. Funds from all sources grew at approximately the same rate; Federal funds, however, were especially important in computer science. (See p. 82.)*
- *The number of supercomputing facilities in the U.S. more than doubled between 1983 and 1985. University installations increased from 3 to 14 centers, and industry added 30 centers to more than double its supercomputing resources. (See p. 85.)*

Previous chapters have described how the people who contribute to science and technology in the United States are recruited and trained. This chapter describes the resources—including funding support—that these persons rely on in their research and development activities.

This discussion particularly focuses on a portion of the overall R&D effort which recently has been receiving special attention: academic R&D and nonacademic basic research. These two complementary activities are increasingly viewed as critical to national R&D strategy, because together they form a crucible for exchanging new ideas and information produced through research.

In the academic context, basic and applied research, as well as the small amount of development activity, are tied closely to the growth of disciplinary knowledge. The results of academic R&D generally are published in the open literature, thereby adding to public knowledge. On the other hand, basic research in industry, nonprofit institutions, and government laboratories is more frequently directed to specific, practical goals rather than to disciplinary knowledge growth. Researchers from these institutions also participate in an open exchange of information, however, contributing their own fundamental

advances and drawing on those coming from the academic world. The interaction between academic and non-academic researchers is a crucial process in effectively using new science and engineering knowledge to meet national goals.

While academic R&D and nonacademic basic research are not exactly the same kind of activities, they have enough in common—and are important enough to innovation in the national research system—to discuss them together at length.

The capital stock of science and engineering is another feature of the research system which has received increasing attention as an element of R&D strategy. Data on investment in R&D plant and research instrumentation at universities and colleges are presented herein, along with survey results on their condition. The size and costs of some special research resources, including supercomputers and data archives, are then reviewed.

Interaction between academic and nonacademic researchers is covered in chapter 5, "Academic R&D and Basic Research: Patterns of Performance"; industrial R&D is discussed in chapter 6, "Industrial Research and Technological Innovation."

R&D FUNDING

The strong recent growth in U.S. R&D spending, which has kept it well within competitive range of that of other industrialized nations, is largely the result of Federal investment in defense development efforts. These efforts accounted for \$19 billion of the \$56-billion increase in R&D spending between 1980 and 1986. Industry, on the other hand, has stepped up its funding of basic research and university R&D; however, the vast majority of its funding continues to support in-house development.

International Comparisons

The U.S. makes by far the largest investments in R&D of any Western country. (See figure O-1 in Overview and appendix table 4-1.) Indeed, the U.S. spends more on R&D than the next four countries combined. Recent growth rates show, moreover, that the U.S. generally is keeping up with its competitors in R&D spending growth. Between 1980 and 1985, R&D spending increased by 36 percent in West Germany, 69 percent in Japan, and 204 percent in France, as compared with 74 percent in the U.S. (See appendix table 4-2.)

R&D Funding as a Percent of GNP. The U.S. now invests approximately the same proportion of its GNP in research and development as do the other major noncommunist industrialized countries. In nearly all of these nations, R&D spending has been growing faster than GNP. In recent years, R&D spending in Japan and West Germany has nearly matched R&D spending in the U.S. as a percentage of GNP. (See figure O-2 in Overview and appendix table 4-2.) The recent increase in this proportion has been most dramatic in Japan, where the share went from 2.2 percent in 1980 to 2.8 percent in 1985: this represents a relative increase of 30 percent. In France, the relative increase was 23 percent; in the U.S., 19 percent.

The data in figure O-2 in Overview show that other nations recently have caught up with the U.S. in R&D investments as a percentage of GNP. The nature of these investments must be taken into account, however. If only nondefense R&D is considered, West Germany and Japan have been ahead of the U.S. in R&D spending for 15 years, and their rate of civilian R&D investment as a percentage of GNP has been rising faster than that of the U.S. for the past 5 years. (See figure O-3 in Overview and appendix table 4-3.) In the nondefense area, France has been catching up to U.S. levels, especially in the 1980's, while the United Kingdom has been falling behind.

Funding Sources. The share of R&D funding in the U.S. from business sources is smaller than in Japan or West Germany, but larger than in the U.K. or France. (See figure O-4 in Overview and appendix table 4-1.) In the United States, nongovernment sources provided 51 percent of R&D funds in 1986, of which nearly 48 percent were provided by industry. There has been a higher proportion of industrial R&D funding in all countries but France, where government R&D funding has shown very sharp growth in the early 1980's. In Japan, the trend in increased industry spending is most pronounced since 1979. In West Germany, there has been a steady increase

in the industrial share since 1975. Finally, in the United States, a strong upward trend in the 1970's in industry R&D funding appears to have slowed in the 1980's.

Performers

Industry remains the largest performer of R&D in the United States, as well as the fastest growing one. (See appendix table 4-4.) In 1986, industry spent 73 percent of U.S. R&D funds, up from 71 percent in 1980. Nearly two-thirds of the funds spent on industry research and development came from industrial sources, and a little more than one-third from the Federal Government. (See appendix table 4-5; a more detailed discussion of industrial R&D funding appears in chapter 6, "Industrial Research and Technological Innovation.")

In 1986, 12 percent of U.S. R&D funds were spent in Federal laboratories; another 12 percent were spent in universities and colleges and in Federally funded research and development centers (FFRDC's) run by universities. Nonprofit institutions also draw their research and development funding support from more than one source: about 70 percent of the funding, however, are estimated to come from the Federal Government. (Funding sources for academic R&D are discussed later in this chapter.)

Character of Work

In the 1980's, support for development has grown at a faster rate than has support for either basic or applied research. (See figure O-5 in Overview and appendix table 4-6.) This trend is confined, however, to Federal defense R&D spending. (See figure O-6 in Overview and appendix table 4-37.) Federal defense funds for development—totaling \$37 billion in 1987—have more than tripled since 1980, while Federal nondefense development spending—\$5 billion in 1987—shrank by 18 percent.

For the same period in industry, growth in development spending lagged behind growth in support for basic and applied research.¹ Basic research made up 5 percent of industry R&D funds in 1986, while applied research was 23 percent. Despite its rapid growth rate throughout the 1980's, industry support for university R&D remains a tiny share (1 percent) of total industry R&D spending. (See following discussion on funding for academic R&D.)

Basic research, applied research, and development are performed to varying degrees in all the Nation's research institutions. (See figure O-23 in Overview and appendix table 4-7.) Industry dominates development activities: in 1985, industrial firms spent \$59 billion of the \$71 billion spent on development. Outside of industry, Federal Government laboratories accounted for nearly \$8 billion in development expenditures in 1985; FFRDC's spent just over \$3 billion. In applied research, industry is again the largest performer, accounting for \$15 billion (65 percent) of the \$23 billion spent on applied research in 1985. Both

¹National Science Foundation (1986b).

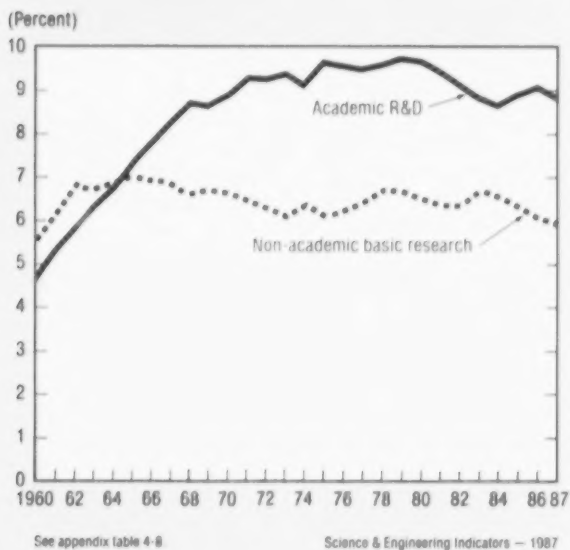
Federal Government laboratories and universities and colleges also participate to a significant degree in applied research, spending \$3.1 billion (13 percent) and \$2.6 billion (11 percent), respectively. The largest share of basic research is done by universities and colleges (48 percent in 1985); industry is the second largest performer in this, at 20 percent in 1985.

FUNDING FOR BASIC RESEARCH AND ACADEMIC R&D

Between 1975 and 1987, academic R&D expenditures remained stable at about 9 percent of R&D spending. Nonacademic basic research spending also stayed flat at about 6.5 percent. (See figure 4-1.) Similarly, applied research spending outside universities and colleges was also relatively stable, at slightly less than 20 percent of R&D. (See appendix table 4-9.)

Figure 4-1.

Academic R&D and nonacademic basic research as a percent of total R&D



Funds for Academic R&D

Sources of Support. Universities and colleges remained largely dependent on the Federal Government for R&D support in 1985, although funding from industry and institutional sources has been rising. (See appendix table 4-10.) In 1987, the Federal Government was estimated to have provided 63 percent of total R&D funding for universities and colleges. This was down from 68 percent in 1980, bringing the Federal Government to its lowest share of support since 1960. In contrast, institutional funds reached their highest proportional share since

these data were first collected in 1953.² Institutional funds covered 17 percent of the costs of separately budgeted research in 1986, as compared with 14 percent in 1980.³

Industry support is estimated to have increased in 1987 to 6 percent; this was up from 4 percent in 1980. Industry funding was the fastest growing segment of university research support between 1980 and 1985, expanding by 75 percent in constant dollars. (See appendix table 4-10 and figure O-31 in Overview.) Philanthropic contributions earmarked for research are estimated to have grown 85 percent (in current dollars) during that time.⁴

Among Federal agencies, the National Institutes of Health (NIH) obligated the largest amount for academic R&D—estimated at \$2.8 billion in 1987. (See appendix table 4-11.) According to the estimated funding figures for 1987 (see appendix table 4-11), the National Science Foundation (NSF) relinquished its long-held second place in support of academic R&D to the Department of Defense (DoD). In 1987, NSF obligated \$1.1 billion for this purpose, and DoD \$1.2 billion, thus recreating the relative rank order that existed prior to 1970.

Forms of Support. Although the Federal Government's share of academic research support has remained relatively stable over the past 2 decades, the form of this support has not.⁵ (See figure 4-2.) For example, in 1966, 42 percent of Federal obligations to universities and colleges for R&D were designated for fellowships, traineeships, training grants, R&D plant, and general support for S/E activities (labeled "infrastructure" in the figure). By 1985, Federal support in these categories had declined to a combined 12 percent. At the same time, funding of research projects grew from 58 percent to 88 percent of the total. Also between 1966 and 1985, the indirect cost share of total Federal obligations for academic R&D increased from about 7 percent to about 28 percent. (See figure 4-2.)

Proposal Activity

Recent survey data comparing proposal activity in 1986 to that in 1980 reflects the growing significance of sponsored research for academic faculty members.⁶ Increases in both proposals submitted and proposals funded outstripped faculty growth. Excluding the social sciences, proposal submissions increased at rates ranging from 110 percent in computer science to 4 percent in geosciences. Although the number of proposals awarded increased in 1986, the proportion funded (excluding pending submissions) was down from 1980 in most fields. Nonetheless, the growth in funded proposals exceeded the increase in

²The category "institutional funds" includes unrecovered indirect costs on externally sponsored research.

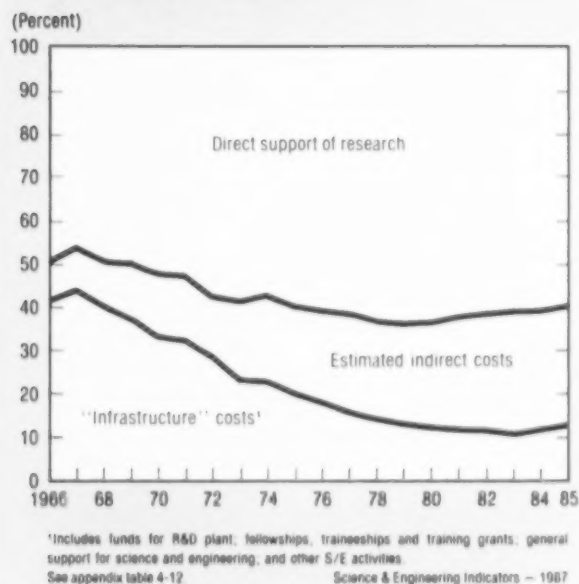
³Separately budgeted research is specifically organized to produce research products and is sponsored by an agency either external to the university or separately budgeted by an organizational unit within the institution.

⁴Personal communication from Hayden Smith, Council for Financial Aid to Education.

⁵U.S. General Accounting Office (1986), p. 40.

⁶The survey collected information on full- and part-time faculty from 2,070 departments in 21 fields at 181 doctorate-granting institutions. See National Science Foundation (1987c).

Figure 4-2.
Percent of Federal research and development obligations to universities and colleges, by major form of funding



faculty in most fields; therefore, the average ratios of funded proposals to full-time faculty were up in 1986.

In the three social sciences fields covered by the survey, both proposal submissions and the number of funded proposals were down in 1986. However, submissions dropped more than did funded proposals; success rates thus were higher in social science fields. As in the other fields, the ratios of funded proposals to full-time faculty were up in 1986.

Funds for Nonacademic Basic Research

The Federal Government was also the main source of support for nonacademic basic research; this included the FFRDC's run by universities, industry, and nonprofit organizations. (See appendix table 4-13.) In 1985, 64 percent of the total funding for nonacademic basic research came from Federal sources, while 33 percent were provided by industry.

FFRDC's and Federal Intramural Laboratories. The Department of Energy (DOE) provided the bulk of the basic research obligations to FFRDC's. (See appendix table 4-14.) DOE spent an estimated \$744 million on these in 1987—82 percent of total FFRDC support. The National Science Foundation obligated \$92 million (10 percent).

Federal intramural basic research is concentrated in a somewhat different set of agencies: NIH (which spent an estimated \$700 million in 1987, or 32 percent of the total), National Aeronautics and Space Administration (NASA) (19 percent), the Department of Defense (12 percent), and

the Department of Agriculture (14 percent).⁷ (See appendix table 4-15.) Basic research funding from all of these agencies for both FFRDC's and government laboratories increased by about 34 percent from 1980 to 1987 in constant 1982 dollars.

Industrial Basic Research. Support for basic research in industry largely comes from companies' own funds: in 1987, 80 percent of basic research expenditures were estimated to have come from companies' own financial resources. (See appendix table 4-16.) The non-Federal share has been fairly constant for the past 2 decades. Nearly 60 percent of the 1987 Federal obligations for industrial basic research came from NASA. (See appendix table 4-17.) DoD was the second largest contributor with 23 percent. Two industries—electrical equipment and aircraft and missiles—received most of the Federal funds.⁸

Funding by Fields of Science and Engineering

Federal basic research obligations provide the best indicator of overall spending by S/E field, since information on non-Federal spending is not available by field for all performing sectors.

In 1987, an estimated 12 percent of Federal basic research funds went to engineering and 88 percent to science. (See appendix table 4-18.) Federal support for engineering has grown somewhat faster than has support for science over the past decade, increasing between 1976 and 1986 by 92 percent in constant 1982 dollars versus 56 percent for the sciences. Between 1985 and 1986, obligations for basic engineering research increased 6 percent in constant dollars, as compared with less than 1 percent for the sciences.

The life sciences received an estimated 47 percent of the science and engineering total in 1987, followed by the physical sciences at 24 percent. (See appendix table 4-18.) Among the sciences, mathematics and computer science grew most quickly; both increased by 94 percent in constant dollars over the past decade. More recently, however, psychology and the social sciences experienced the most rapid growth, increasing in constant dollars by an estimated 10 percent and 13 percent, respectively, between 1986 and 1987.

Universities and Colleges. In 1986, 85 percent of academic R&D spending was in science; the remaining 15 percent was spent on engineering. (See appendix table 4-19.) Over the last decade, expenditures for engineering R&D in the academic sector have been growing faster than has spending for R&D in the sciences. Engineering spending increased by 106 percent between 1976 and 1986 in constant dollars, as compared with a growth of 53 percent in the sciences. (See figure O-24 in Overview and appendix table 4-19.)

Slightly more than one-half (54 percent) of academic R&D spending went to the life sciences. Of this amount, 24 percent went to the medical sciences, 17 percent to the

⁷These numbers should be taken as approximate, since the obligations figures for intramural research also include agency expenditures for managing extramural research programs.

⁸National Science Foundation (1983), table B-3, p. 19.

biological sciences, and 10 percent to the agricultural sciences. (See appendix table 4-19.) Twelve percent of total academic R&D spending supported the physical sciences; this included 6 percent for physics and 4 percent for chemistry. Another 7 percent went to the environmental sciences.

Some of the smaller sciences have been the fastest growing over the past decade. Spending for R&D in computer science, for instance, increased by 292 percent from 1976 to 1986 in constant dollars. Increases in physics, astronomy, and mathematics funding all exceeded inflation by 70 percent or more. On the other hand, funding for the social sciences grew only 16 percent over the decade—slower than the inflation rate during the same period.

Although 62 percent of academic R&D expenditures came from Federal funds in 1986, the percentages by field ranged from a high of 82 percent in physics to a low of 29 percent in the agricultural sciences. (See appendix table 4-20.) The social sciences have the highest share of non-Federal funding (64 percent), and the physical sciences the lowest (23 percent). About equal proportions of academic science and academic engineering funds come from the Federal Government.

Industry. Basic research expenditures in industry are distributed somewhat differently among fields than in university R&D:⁹ notably, in industry, engineering and the physical sciences receive more emphasis and the life sciences less. In 1983, engineering research received 32 percent of total industrial basic research funds; this was more than twice the share of engineering in university R&D. (See appendix table 4-21.) Similarly, chemistry received 26 percent of industrial spending (43 percent went to the physical sciences as a whole), as compared with only 4 percent of university spending (12 percent for all physical sciences). On the other hand, the life sciences consumed only 13 percent of industrial basic research spending, versus 54 percent of academic R&D funding.

From 1973 to 1983, basic research spending in industry more than tripled in current dollars—a 59-percent growth in constant dollars. (See appendix table 4-21.) Basic research activities grew at similar rates across most S/E fields, with somewhat more rapid growth occurring in the relatively small areas of the geological and atmospheric sciences. Basic research in engineering and the biological sciences were also expanding rapidly, growing 35 percent and 39 percent, respectively, between 1981 and 1983 in constant dollars.

PLANT AND EQUIPMENT

The plant and equipment available for use at research-performing institutions are another major R&D resource. Unfortunately, information on this aspect of the research infrastructure is fragmentary: estimates of the national stock of research facilities and instrumentation are available only for universities, and the data on R&D plant spending are more complete for universities than for other sectors. Given this lack of comprehensive data, this

section reports exclusively on universities' aggregate research capital stock.¹⁰

There are several discernible trends in R&D capital stock. First, capital investment in science and engineering is cyclical. Although the long-term trend in constant dollars has been downward over the last 2 decades, the Nation is currently in an upsurge of capital spending for academic science and engineering, with engineering receiving the largest percentage increases. In response to widespread concern over research instrumentation, equipment expenditures have been expanding rapidly in the 1980's. Further, special Federal instrumentation programs are helping to ensure that new instrumentation is accessible to more than the major research universities. Finally, instrument intensity varies among the sciences, but is not necessarily connected to the trend toward shared-access research facilities or to collaboration rates.

Facilities Spending¹¹

Since the 1960's, Federally funded capital S/E expenditures at universities and colleges have been declining in constant dollars, and fluctuating in current-dollar terms. (See figure O-25 in Overview and appendix table 4-22.) For example, in 1966, Federal support for academic science and engineering facilities reached its highest proportional share (32 percent); in 1985, it was at its lowest point ever (11 percent). Since 1979, however, the Nation's total capital spending in universities and colleges has been on the upswing. In 1986, expenditures on facilities for research and instruction in science and engineering were 99 percent higher in current dollars than they had been in 1980, and 20 percent higher than they had been 1 year earlier. (See appendix table 4-22.)

The largest share of funds (80 percent) from the current increase in capital spending is going to science rather than engineering. (See appendix table 4-23.) However, spending on engineering facilities expanded rapidly from 1984 to 1986 for a total increase of 121 percent in current dollars.

Among the sciences in 1986, capital spending in the life sciences received the largest share: two-thirds of all funds for science facilities, or 53 percent of the S/E total. (See appendix table 4-23.) Capital spending in the life sciences was growing slowly; it was only 19 percent higher in 1986 than in 1976. In contrast, capital spending in the physical sciences was 107 percent higher at the end of that period. In the mathematical and computer sciences, 1986 spending was more than 2.5 times the 1976 figure. Spending on

⁹There is no continuous collection of data on industry R&D plant, but attempts have been made to describe new investments systematically. See (for example) Conference Board (1987). For figures on Federal obligations for R&D plant, see National Science Foundation (1985c), (1986a), and (1987b).

¹⁰The term *facilities* is used here to stand for capital investment expenditures for S/E research or instruction at those universities and colleges spending \$50,000 or more annually on separately budgeted R&D. The constant-dollar calculations are based on the GNP price deflator. The figures include some money for major equipment purchased from capital, rather than from current operating funds, but there is no way of knowing how much. For more information on definitions, see National Science Foundation (1985b).

¹¹Data on basic research by field are not available for universities.

psychology facilities in the same period had nearly tripled, but spending for the other social sciences was only up 15 percent. In the environmental sciences, the level of investment was actually 4 percent lower in 1986 than in 1976 (current dollars).

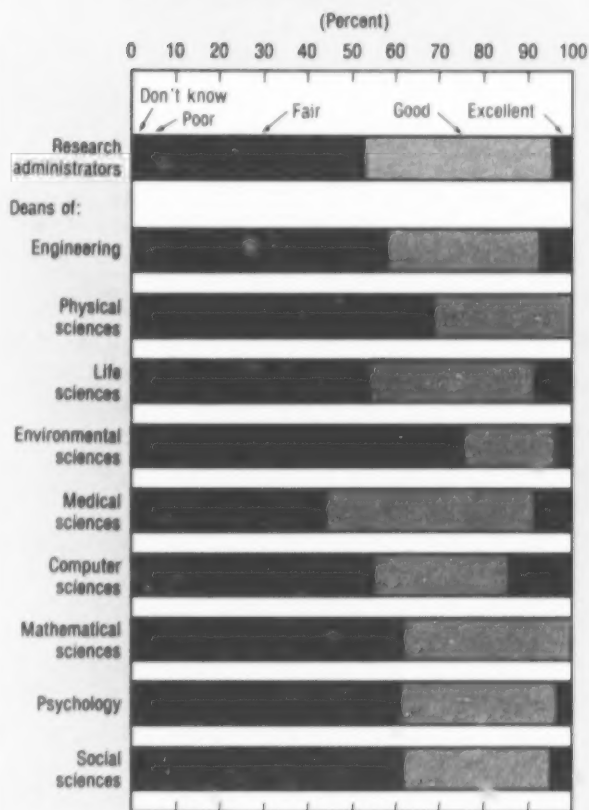
Condition of Facilities. As shown in figure O-25 in Overview, real-dollar investments in academic science and engineering facilities have declined during the last 18 years. However, the level of need for research facilities depends on more than just capital expenditures. On the one hand, if adequate facilities are established, they may be sufficient for decades. On the other hand, existing facilities can become inadequate through lack of maintenance.¹² They can become crowded if the number of researchers grows, and can become obsolescent through changes in the character and technology of research.

Indicators of the status and condition of facilities in selected S/E fields are available from a 1986 survey among doctorate-granting research universities.¹³ The survey showed that although the average institution devotes 513,000 square feet on campus to research, the figures for individual campuses ranged as high as 3.3 million square feet. The average for the top (in terms of R&D expenditures) 50 schools was 1.032 million square feet. More than one-half of the universities surveyed were in the process of building new research facilities that would result in a net average increase of 73,000 square feet per campus. The top 50 schools had an average of 98,000 square feet under construction; the other schools averaged 58,000.

The overall condition of university research facilities was appraised in the survey by deans and research administrators in the relevant S/E fields. (See figure 4-3.) Facilities in the medical sciences¹⁴ were judged to be in the best condition: 56 percent were rated excellent or good by the deans. Facilities for the environmental sciences—where investment has trailed off—were found least satisfactory. Seventy-three percent of the deans rated facilities in that field fair or poor, and only 24 percent judged them to be in good or excellent condition. Only 31 percent of the deans considered their schools' physical sciences facilities to be in good or excellent condition, despite the rapid increase during the past decade in spending in that area (noted in appendix table 4-23).

Administrators and deans surveyed felt that lack of space was a more pressing problem on their campuses than was the quality of the existing space. About one-third of the respondents considered facilities to be the most pressing problem on their campuses in the next 5 years. About one-half judged the facilities on their cam-

Figure 4-3.
Academic officials' views regarding condition of research facilities: 1986



See appendix table 4-24.

Science & Engineering Indicators — 1987

puses to be in good or excellent condition; about one-half judged them to be in fair or poor condition.

Survey respondents reported that their facilities in virtually every field were crowded. (See figure 4-4.) Engineering was identified as having the most serious space problem, closely followed by the social sciences. The mathematical sciences were least crowded, although only one-third of the deans felt that those facilities provided adequate space.

Facilities Plans. Three-quarters of the schools surveyed in 1986 expected to construct new research facilities within the next 5 years. In addition, 77 percent of the schools surveyed reported that they were upgrading or renovating facilities, and 74 percent were undertaking major repairs in academic year 1985/6. Engineering was the area of greatest facilities construction activity: two-thirds of the institutions with engineering programs were building or planning to build new engineering facilities within the next 5 years.

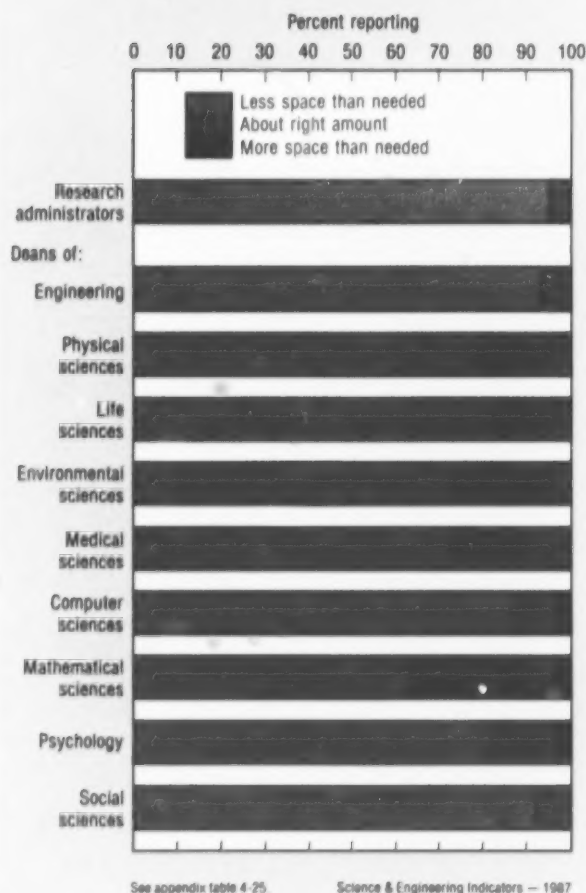
According to survey respondents, State Governments—at 40 percent of total funding—provided the

¹²Maintenance expenditures are not included in the data in figure O-25 in Overview.

¹³This survey inquired about research facilities only; it did not include information on equipment or instructional facilities. The survey thus has a narrower scope than does the data on spending reported in the last section. In addition, the sample of universities was different than the set used to gather the capital expenditures data. For more detailed information, see National Science Foundation (1986c).

¹⁴"Medical sciences" is a subcategory of life sciences used for this particular study.

Figure 4-4.
Academic officials' views regarding
sufficiency of research space: 1986



highest proportion of new construction funds. Tax-exempt bonds funded 30 percent of new construction costs, 14 percent was derived from private donations or endowments, and Federal funds covered 10 percent. Private institutions were more dependent than public ones on Federal funding. The administrators anticipated that 10 percent of the new construction costs (1986-91) of private schools would be financed with Federal funds as compared with 4 percent of new construction at public institutions.¹⁷

¹⁷ See National Academy of Sciences (1986), pp. 32-38, for a discussion of alternative sources of finance for facilities funding.

Equipment Spending¹⁸

Equipment expenditures from current (rather than capital) funds have also increased dramatically in recent years. (See figure O-25 in Overview.) In 1986, U.S. universities and colleges spent \$765 million from their current fund accounts on research equipment. These expenditures more than doubled since 1980 (58-percent increase in constant dollars), the first year for which data are available; facilities investments, in contrast, increased only 99 percent during the same time period. Sixty-five percent (\$497 million) of the funds spent on equipment came from the Federal Government. While this percentage closely matches that for overall Federal support of university R&D (i.e., 64 percent), it far exceeds the Federal share of facilities expenditures (11 percent). Federal support for instrumentation increased at a slightly slower pace than did non-Federal support: a 106-percent increase from 1980 to 1986 as compared with 119 percent in non-Federal support. (See appendix table 4-26.)

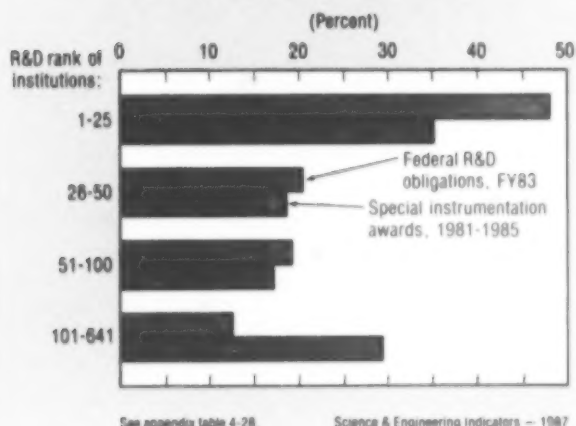
Between 1980 and 1986, spending for equipment in the life sciences grew more slowly than spending in all fields combined (68 percent as compared with 111 percent). Equipment expenditures in the physical sciences, on the other hand, increased at nearly twice the average rate (205 percent between 1980 and 1986). Expenditures in engineering more than doubled over this time period, increasing by 145 percent.

Special Programs. The growth in Federal funds for research equipment is due in part to instrumentation programs implemented in several agencies during the early 1980's. The National Science Foundation, Department of Defense, Department of Energy, and National Institutes of Health all had initiatives in this area. The amounts awarded by these programs represented only about 26 percent of overall Federal support for instrumentation by 1985, but—as shown in appendix table 4-27—the programs were growing very quickly.

These special programs helped distribute Federal instrumentation to a wide set of universities. A comparison of total Federal R&D funds to groups of universities and those funds distributed through special instrumentation programs is presented in figure 4-5. Excluding the top 100 in Federal R&D support, the remaining universities received 12 percent of overall Federal R&D funds; however, these same universities received nearly 30 percent of the funds awarded under special instrumentation programs. When all Federal instrumentation awards (both overall and special program) are considered, funding for non-top-100 universities more closely matches their share of total R&D funding. These data suggest that the special programs have performed a complementary distributive function that the research project grant system alone has not performed.

¹⁸ Data here refer to expenditures from current (operating) funds for research equipment, in contrast to the capital funds reported earlier in this chapter. Most universities keep separate current and capital funds, and apply current funds for ongoing activities. Note also that the data used here are limited to funds for research equipment, and do not include funds for instructional equipment. The term *instrumentation* is used throughout this chapter to refer to research equipment.

Figure 4-5.
Comparison of awards to colleges and universities under special Federal instrumentation programs with total Federal R&D obligations, by R&D rank of institutions



The instruments awarded under the four agency programs match reasonably well those types of instruments that universities say they need. A 1982-83 survey asked departmental chairpersons and facilities administrators to name the three instruments their departments most needed to purchase.¹⁷ The match between the instruments awarded under the four agency instrumentation programs and the needs expressed by the administrators is shown in figure 4-6. Computers and spectrometers were the instruments named most frequently, and they also were awarded most frequently by Federal programs. Computers, however, made up a smaller share of awards than of needs expressed by the administrators; the figures were closer for spectrometers.

Instrument inventory. In 1982/83, more than 46,000 large instrument systems (with an original cost ranging from \$10,000 to \$1 million) were located on university campuses, according to an estimate based on the survey sample.¹⁸ The estimated aggregate purchase price of the equipment was \$1.6 billion.¹⁹ Between 1982 and 1985, there was substantial turnover in research equipment in the physical sciences, engineering, and computer science. (The other fields have not yet been resurveyed.) In the physical sciences and engineering, roughly one-fourth of the instrument systems that were in active use in 1982 were no longer being used in 1985. Conversely, almost one-half of the systems being used for research in 1985 had been acquired in the 1983-85 period. In com-

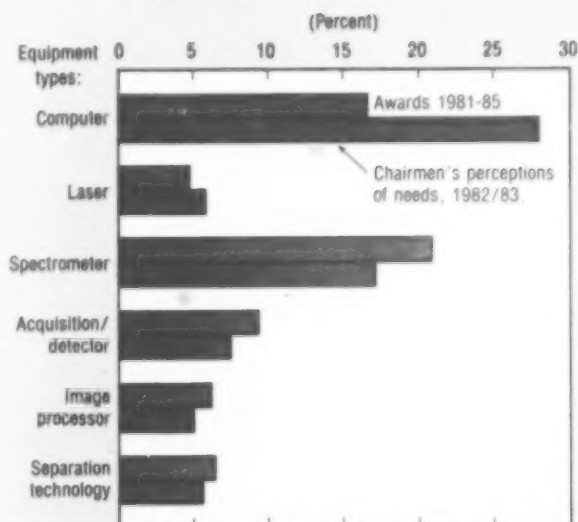
puter science, turnover rates were even higher: more than 40 percent of the equipment in research use in 1982 had been retired by the end of 1985, and three-fourths of the systems in research use in 1985 had been acquired since the 1982 study.²⁰

Of the systems in use at the time of the 1982/83 survey, 22 percent were judged by their users to be "state-of-the-art," one-half were considered in excellent condition, and 10 percent in poor condition. Fifty-three percent of the systems were 1 to 5 years old; another 24 percent were 6 to 10 years old. Of those systems purchased within the last 5 years, 68 percent were thought to be in excellent condition, a rating applied to only 27 percent of those more than 10 years old. (See figure 4-7.)

A number of indicators suggest that, between 1982 and 1985, the general quality of academic research instrumentation has improved in the three fields that have been resurveyed. For example, the proportion of all existing research equipment that is completely inactive (and presumably obsolete, either mechanically or technologically) declined by 3 to 10 percent in all three fields. Also, the number of instrument systems judged by the responsible principal investigators as state-of-the-art increased by 48 percent in engineering, 73 percent in the physical sciences, and 167 percent in computer science. Furthermore, the extent of reliance on non-state-of-the-art equipment declined in all three fields: the proportion

²⁰National Science Foundation (1987a).

Figure 4-6.
Comparison of perceived instrumentation needs with awards under special Federal instrumentation programs, by type of equipment

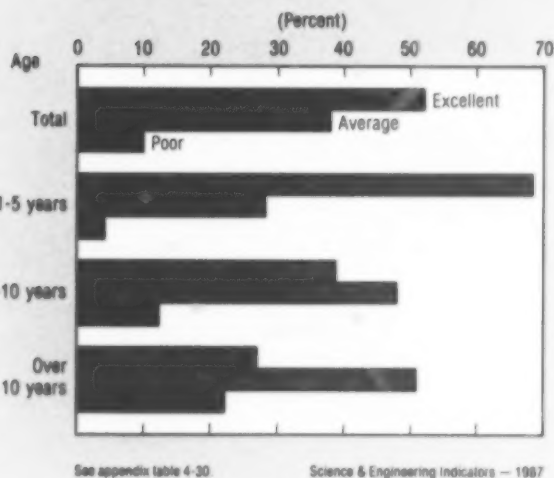


¹⁷National Science Foundation (1985a).

¹⁸Ibid.

¹⁹Not all of the equipment on campus at the time of the survey was in use: 2 percent had not yet come on line, and 20 percent had been retired. Only those systems in use are discussed here.

Figure 4-7.
Condition of academic research instrument
systems by age of system



of non-state-of-the-art instrument systems that were the most advanced instruments to which their users had access declined by 7 percent in engineering, 9 percent in the physical sciences, and 19 percent in computer science.²¹

Research equipment expenditures at universities and colleges are approximately proportional to equipment inventory share by S/E field. The 1983 baseline survey showed that the largest stock of equipment was devoted to the life sciences (38 percent), followed by the physical sciences (25 percent), and engineering (20 percent).²² (See appendix table 4-31.) In 1986, the life sciences spent 42 percent of current fund expenditures for research equipment, the physical sciences received 21 percent, and engineering used 18 percent. (See appendix table 4-26.)

Maintenance and Repair. Total maintenance and repair costs for research instruments are roughly proportionate with instrument spending. (See appendix table 4-32.) According to the 1983 survey, the average is 16 percent of total equipment expenditures, with variations ranging from 12 percent in the agricultural sciences to 21 percent in computer science. Approximately 40 percent of maintenance expenditures were for service contracts and field service; 40 percent were for university-employed service personnel; and 20 percent were for service supplies, equipment, and facilities. Forty-one percent of the instrument systems in the survey were located in shared-access facilities, as were 38 percent of state-of-the-art systems.²³

²¹Ibid.

²²These percentages are calculated using the purchase price of the equipment systems. The data are limited to systems that cost between \$10,000 and \$1 million, and are estimated based on a sample of universities. See National Science Foundation (1985a).

²³The pattern of shared-access facilities by field is discussed in the following section.

Instrument Intensity. As noted above, there was a high rate of increase in equipment spending for the physical sciences; this increase is reflected in a correspondingly high level of instrumentation spending per physical scientist. (See appendix table 4-33.) The 1983 equipment inventory showed an average of \$24,800 worth of equipment per scientist in the physical sciences; in chemistry, the figure was \$27,100. The environmental sciences are also very equipment-intensive by this measure, with \$18,000 worth of equipment per academic scientist.

Another form of equipment intensity is the use of shared-access facilities. (See appendix table 4-34.) In 1983, 41 percent of instrument systems were located in such facilities. Materials science and computer science showed the highest percentages of instruments in shared facilities (81 percent in each case). Engineering instruments and those used in the environmental sciences were also relatively likely to be shared (50 and 48 percent respectively), as were instruments for interdisciplinary research (73 percent). The most equipment-intensive fields, however—as measured by the value of the equipment inventory per scientist—are *not* those in which instruments are housed in shared facilities. The physical sciences, for instance, show a low percentage of instruments in shared-access facilities (35 percent).

Newer systems are generally less likely than older ones to be located in shared-access facilities. (See appendix table 4-35.) Thirty-eight percent of the systems that were less than 5 years old at the time of the inventory were shared, as compared with 48 percent of those more than 10 years old. Only in the agricultural and environmental sciences was this trend reversed, with newer systems more likely to be shared than older ones.

Cross-Institution Collaboration. Shared instrumentation is often seen as a major factor in the increase of S/E collaboration among researchers working in different institutions. The figures on institutional collaboration suggest, however, that instrumentation is not the only factor involved. In fact, collaboration rates have increased in equipment-intensive fields, but they have gone up in other fields as well. (See appendix table 4-36.) This type of collaboration has grown from 24 percent of all published articles in 1973 to 36 percent in 1984. The fields with the highest levels of institutional collaboration are *not* those that are most equipment-intensive or those in which equipment is most often located in shared-access facilities. Clinical medicine has the highest collaboration rate: more than one-half of all articles in that field were coauthored across institutions in 1984. It is followed by the earth and space sciences and the rest of biomedicine. Chemistry, the most equipment-intensive field, is one of the least collaborative (24 percent of 1984 articles), as is mathematics (also at 24 percent). Of course, patterns of institutional collaboration within fields may be related to instrument use even if comparisons across fields do not show the connection.

SPECIAL RESEARCH RESOURCES

Many research areas require special resources beyond buildings, equipment, and the expenses of ongoing re-

search. Computing facilities are an example. Archives of data and research materials are important in many disciplines, as are highly specialized research facilities. This section discusses some instances of such resources.

Supercomputers

Supercomputers provide enhanced problem-solving capabilities to researchers in many disciplines. Supercomputing capacity is increasing rapidly among U.S. research-performing institutions. The number of supercomputer facilities in the U.S. more than doubled between 1983 and 1986 (see table 4-1); university supercomputing resources increased in this period from 3 to 14 centers.²⁴ The largest number of supercomputing installations (34) was added in government laboratories; 30 new installations appeared in industry. Comparable numbers for supercomputer installations in Japan show even faster growth.

Collections of Research Materials

Among the capital resources of many fields are archives of research materials. The collections themselves can be vast, even though the costs of managing and maintaining them are modest. For instance, nearly 4,000 collections of biological materials that serve as the basis for systematic and evolutionary biology have been identified in the United States.²⁵ About two-thirds of these, it is estimated, are maintained in academic departments. Another 29 percent are housed in freestanding institutions or academic museums. Because many of the collections are small and have no special funds allocated for management, the average budget for the collections is low: \$5,620 in 1981. Budgets ranged as high, however, as \$1.5 million

that year. The estimated total cost of collection management for 1981 was nearly \$15 million.

Other areas of biology depend on libraries and stocks of living organisms. For instance, a gene library project is under way at Lawrence Livermore and Los Alamos National Laboratories.²⁶ The project purifies and packages chromosomes for use by researchers studying and diagnosing genetic disease, linkage, and pedigree analysis, as well as those studying gene structure and regulation. A multi-million dollar project to map the human genome is also under consideration.²⁷ In the agricultural sciences, a network of institutions makes germplasm available for research purposes. More than 400,000 samples have been acquired by the National Plant Germplasm System, and another 7,000 to 15,000 domestic and foreign additions are made annually.²⁸ Sixteen such data collections were supported by NSF in 1986 for a total of \$1.6 million; the Department of Agriculture and NIH sponsor other collections.²⁹

Earth and environmental scientists depend on publicly maintained archives of data resources in their work. In the earth sciences facilities exist for storing ocean-bottom sedimentary cores, ice cores, and meteorites. In 1983-84, one collection alone distributed 6,179 samples of ocean-bottom cores.³⁰ Archives of computerized data from weather satellites also are growing at a rapid rate. The National Environmental Satellite, Data, and Information Service—which manages earth-observing satellite systems and global data bases in meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences—has been adding 30 million meteorological observations annually to its collection.³¹

²⁴These libraries are available from a repository through funding by the NIH Division of Research Resources.

²⁵See the Spring 1987 issue of *Issues in Science and Technology* for a discussion of this project.

²⁶Source: Agricultural Research Service.

²⁷Information provided by the National Science Foundation, Division of Biotic Systems and Resources.

²⁸Cassidy (1984), pp. 243-245.

²⁹Information provided by the National Oceanic and Atmospheric Administration.

²⁴Five of these centers were supported by the National Science Foundation, at the University of Illinois, the Von Neumann Center in Princeton, Cornell University, the University of California at San Diego, and the Pittsburgh Supercomputer Center.

²⁵Edwards, Davis, and Nevling, eds. (1985).

Table 4-1. Supercomputer installations in the United States and Japan: 1983-86

Type of installation	1983		1984		1985		1986	
	United States	Japan	United States	Japan	United States	Japan	United States ²	Japan
Government research laboratories ¹ ..	23	{ 2 }	26	{ 4 }	39	{ 9 }	57	{ 19 }
Universities ¹	3	{ 2 }	5	{ 4 }	14	{ 9 }	14	{ 19 }
Industry	20	3	22	9	46	17	50	33

¹ The categories "government research laboratories" and "universities" cannot be separated in the Japanese environment.

² Estimated.

SOURCE: United States: National Science Foundation, Office of Advanced Scientific Computing; Japan: Tokyo Office of the U.S. National Science Foundation, Report Memorandum #128, July 23, 1987

In the social sciences, several national survey data bases both serve as archives for historical patterns and provide information on current trends. The Panel Study of Income Dynamics, for instance, is the only survey of income, occupation, education, family composition, and other social and economic family characteristics which has repeatedly interviewed the same nationally representative sample of respondents over a significant period of time. The data are invaluable in analyzing income and labor supply dynamics. Similarly, the National Election Studies and General Social Survey track political and

social trends. As in the earth sciences, archives of social science data are of continuing importance. NSF's Division of Social and Economic Sciences now requires data produced under some Federal grants to be made publicly available. The International Association for Social Sciences Information Services and Technology provides information on archives around the world.¹⁰

¹⁰Information provided by the National Science Foundation, Division of Social and Economic Sciences.

REFERENCES

Cassidy, D.S., "Antarctic Marine Geology Research Facility and Core Library, 1983-1984," *Antarctic Journal of the United States*, Vol. 19, No. 5, 1984.

Conference Board, "Locating R&D Facilities," Report #892 (January 1987).

Edwards, S.R., G.M. Davis, and L.I. Nevling, eds., *The Systematics Community* (Lawrence, KS: Association of Systematics Collections, July 1985).

Issues in Science and Technology, Vol. III, No. 3, Spring 1987.

National Academy of Sciences, *Academic Research Facilities: Financing Strategies*, report of a conference July 22-23, 1985 (Washington, DC: National Academy Press, 1986).

National Science Foundation, "Academic Research Equipment in the Physical and Computer Sciences and Engineering: 1982 and 1985" (Washington, DC: National Science Foundation, September 1987a).

National Science Foundation, "Academic Research Equipment in Selected Science/Engineering Fields, 1982-83" (Washington, DC: National Science Foundation, August 1985a).

National Science Foundation, *Academic Science and Engineering, R&D Funds* (Washington, DC: National Science Foundation, 1985b).

National Science Foundation, *Federal Funds for Research and Development, Fiscal Year 1985* (Washington, DC: National Science Foundation, 1985c).

National Science Foundation, *Federal Funds for Research and Development, Fiscal Year 1986* (Washington, DC: National Science Foundation, 1986a).

National Science Foundation, *Federal Funds for Research and Development, Fiscal Year 1987* (Washington, DC: National Science Foundation, 1987b).

National Science Foundation, *National Patterns of Science and Technology Resources* (Washington, DC: National Science Foundation, 1986b).

National Science Foundation, *Science and Engineering Faculty at Research-Intensive Institutions: 1986* (Washington, DC: National Science Foundation, 1987c).

National Science Foundation, "Science and Engineering Research Facilities at Doctorate-Granting Institutions" (Washington, DC: National Science Foundation, September 1986c).

National Science Foundation, *Trends to 1982 in Industrial Support of Basic Research*, NSF 83-302 (Washington, DC: National Science Foundation, 1983).

U.S. General Accounting Office, *University Funding: Federal Funding Mechanisms in Support of University Research*, GAO/RCED-86-53 (Washington, DC: General Accounting Office, February 1986).

Chapter 5
Academic R&D and
Basic Research: Patterns
of Performance

Academic R&D and Basic Research: Patterns of Performance

HIGHLIGHTS

- *In 1985, almost one-half (49 percent) of the doctoral-level scientists and engineers in academic research and development (R&D) or basic research were supported by Federal funds. This proportion has dropped in recent years, down from 56 percent in 1977. In industry, the percentage dropped from 21 to 14 percent, and in universities and colleges from 55 to 48 percent. (See pp. 90-91.)*
- *The number of doctoral-level women scientists and engineers engaged in academic R&D or nonacademic basic research nearly doubled between 1975 and 1985. In the same period, the percentage of women in these activities increased from 9 percent to 15 percent. (See p. 91.)*
- *The number of doctoral-level blacks, Asians, and other minority groups also nearly doubled between 1975 and 1985, and the percentage of blacks increased from 0.78 to 1.16 during this period. However, since black enrollment in science and engineering (S/E) degree programs has slowed in recent years, future gains are not likely to be as dramatic. Moreover, black participation in research is still low when compared with the percentage of blacks in the total population of scientists and engineers. (See p. 91.)*
- *The number of scientists and engineers engaged in academic R&D or nonacademic basic research doubled between 1976 and 1985. The fastest increase was among computer specialists, whose numbers went from 1,200 in 1976 to 6,000 in 1984. The number of engineers in research increased by 133 percent between 1976 and 1985. The number of scientists grew 97 percent. (See pp. 93-94.)*
- *The percentage of doctoral-level researchers who moved from universities and colleges to industry was somewhat higher between 1983 and 1985 than it had been a decade earlier. This trend was more notable among scientists than among engineers. Similarly, the percentage of researchers moving from industry to academia also was higher in 1983-85 than a decade earlier. In all cases, however, the proportions were small, around 2 percent. (See pp. 94-95.)*
- *Research collaborations across sectors in the United States are on the rise. In 1973, only 19 percent of articles with authors working in industry were coauthored with someone working in another sector. By 1984, 36 percent were coauthored across sectors, 24 percent with university researchers. Cross-sector collaboration rates were also up for nonprofit institutions, Federally funded R&D centers (FFRDC's), and Federal Government laboratories. (See pp. 95-96.)*
- *Universities and colleges are patenting more frequently. The rate of increase in patents granted between 1980 and 1985 was more than double that for the preceding 5 years. The most active patent classes are bio-affecting drugs, molecular biology and microbiology, and surgical inventions. (See p. 97.)*
- *Foreign citizens received a larger share of the science and engineering doctorates granted by U.S. universities in 1986 than at any time in the preceding decade, and more of these citizens planned to stay and work in the United States. Twenty percent of the S/E doctorates awarded in the U.S. in 1984 went to foreign nationals, as compared with 12 percent in 1960. In 1983, 47 percent of these foreign doctoral recipients had firm plans to stay in the U.S., compared with 29 percent in 1972. In contrast, the number of U.S. nationals who planned postdoctoral study abroad has fluctuated around 1.5 percent of the total for several decades. (See p. 98.)*
- *Cross-national research contacts are on the rise, as indicated by increases in exchange visas and international coauthorships. More than 97,000 academic exchange visas were issued in 1984 to allow overseas visitors to attend U.S. universities and colleges; this represented a 7-percent increase from 1983. Similarly, internationally coauthored articles rose from 13 percent in 1973 to 17 percent in 1982. More than 25 percent of publications from FFRDC's in 1984 were internationally coauthored, as compared with 18 percent for private firms and 16 percent for universities. (See pp. 98-99.)*
- *The U.S. still produces about 35 percent of the world's science and engineering literature, and receives more citations than any other country. In relation to the number of articles produced, however, there has been a slight decrease in world attention to the U.S. literature. The 1982 U.S. literature received only 83 percent as many citations from the rest of the world between 1982 and 1984 as would be expected based on the number of U.S. articles published. (See p. 99.)*

The preceding chapter described those resources available in the United States for research in science and engineering, particularly focusing on resources for academic R&D and nonacademic basic research—two activities that are increasingly treated as critical in national R&D strategy. This chapter focuses on how the people in science and engineering use those resources to produce new knowledge.

The chapter first presents a statistical description of the set of institutions—including universities and colleges, other nonprofit institutions, government laboratories, and industrial firms—that are involved in basic research in some form. Data on U.S. scientists and engineers who are engaged in academic R&D or basic research are presented, and their distribution among fields of science and research-performing sectors is described. Movement of scientists and engineers out of research and into other activities—such as R&D management, development, and teaching—is also discussed.

This chapter also discusses cross-sectoral contacts among researchers, including cross-sectoral mobility, coauthorship, and a variety of university-industry interactions. These contacts are often considered essential if new science and engineering knowledge is to be both useful and used. Finally, data on international contacts, another important consideration in national R&D strategy, are presented.

INSTITUTIONS

Although basic research often is associated with academic settings, nonacademic institutions—i.e., government laboratories, nonprofit institutions, and industrial firms—are also important contributors. Altogether, nearly 1,600 institutions, academic and nonacademic, are involved in the performance of basic research in the United States.¹ Their expenditures vary substantially. Among universities, the top 100 (which account for 18 percent of all academic R&D performers) spend 83 percent of R&D funds. (See table 5-1.) FFRDC's are generally very large organizations, with annual budgets ranging as high as \$688 million in 1985.²

Among industrial firms, the 56 largest R&D-performing companies spent 44 percent (\$1.1 billion) of industry's in-house basic research funds in 1984. (See table 5-2.) Company funds for in-house basic research are heavily concentrated in a few industries: chemicals and allied products, petroleum refining, machinery, electrical equipment, motor vehicles, and scientific instruments. Together these industries account for 78 percent of industry's total basic research expenditures.³

¹The actual estimate of 1,566 institutions includes the 566 universities and colleges that spent at least \$50,000 on separately budgeted R&D in 1984 or granted a graduate science or engineering degree, 38 FFRDC's, and the 228 industrial firms that spent at least \$10,000 on basic research in 1984. Also included are an estimated 444 nonprofit institutions (based on a 1973 survey) and 290 Federal intramural laboratories (based on a data base on laboratories maintained at the Technology and Information Policy Program at Syracuse University).

²National Science Foundation (1987b).

³National Science Foundation (1984).

Table 5-1. Distribution of R&D funds among academic performers, by R&D rank: 1986

R&D rank	Funds	
	(Millions of dollars)	Percent
All institutions	10,718	100
Top 10	2,284	21
Top 20	3,779	35
Top 50	6,516	61
Top 100	8,896	83

SOURCE: National Science Foundation, *Academic Science/Engineering: R&D Funds FY 1985*, and unpublished data

Science & Engineering Indicators—1987

Industrial laboratories have historically performed about one-third of nonacademic basic research, and their efforts in this area are growing faster than those of any other sector. (See appendix table 5-1.) In 1985, industrial laboratories spent \$2.85 billion on basic research activities, an increase of 65 percent in constant dollars over the 1980 level. In comparison, Federal laboratories increased their spending by 25 percent in constant dollars, and universities and colleges increased theirs by 18 percent.

The role of basic research within the various performing institutions varies widely. (See appendix table 4-7.) Universities, colleges, and other nonprofit institutions do more research than development. In contrast, basic research is only a small component of the overall R&D efforts of FFRDC's, government laboratories, and industrial firms.

The mix of institutions performing basic research in the United States is, by and large, typical of industrialized countries. The U.S. spends about the same share of its basic research dollars in industrial laboratories as does West Germany, and a somewhat smaller share than Japan. (See figure 5-1.) All the industrialized nations represented in figure 5-1 spend between one-half and two-thirds of their basic research funds in the higher education sector. The chief distinctive feature of the U.S. system is the high level of participation in basic research by the private nonprofit sector. Since this sector is growing more slowly in the U.S. than either academic R&D or industrial basic research, the patterns may in fact be converging.

SCIENTISTS AND ENGINEERS IN ACADEMIC R&D AND BASIC RESEARCH

Research is only one of a number of activities that scientists and engineers pursue. For example, if they work in universities, they probably combine teaching with research; if they work in nonacademic settings, they may be primarily engaged in development. In either setting, scientists and engineers may spend more time on management than on research itself.

This section focuses on scientists and engineers whose main activity is the extension of knowledge—i.e., re-

Table 5-2. Distribution of R&D expenditures among industry performers, by size of company and character of work: 1985

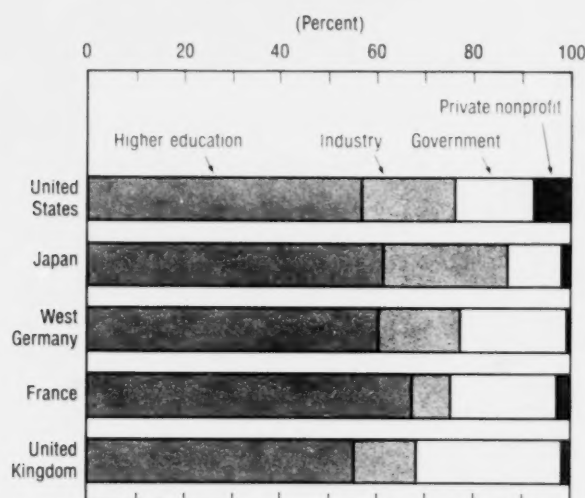
Size of company (no. of employees)	Research & development			Basic research		
	Number of performers	Thousands of dollars	Percent of funding	Number of performers	Thousands of dollars	Percent of funding
Total	NA	71,137	100.0	NA	2,503	100.0
Less than 1,000	NA	3,557	5.0	NA	447	17.9
1,000-4,999	775	4,395	6.2	73	315	12.6
5,000-9,999	185	3,175	4.5	34	138	5.5
10,000-24,999	191	10,332	14.5	65	490	19.6
25,000 or more	127	49,678	69.8	56	1,113	44.5

SOURCE: National Science Foundation, *Research and Development in Industry*, 1985, and unpublished data

Science & Engineering Indicators—1987

Figure 5-1.

Basic research expenditures by performer, selected countries



Note: Data is for a year between 1980-84 depending on the country.
See appendix table 5-2. Science & Engineering Indicators — 1987

search. For data from universities and colleges, "researcher" applies to anyone whose primary or secondary work activity is research or development. This definition is based on the assumption that teaching and research are closely related in the university setting, that most researchers are doing some combination of both basic and applied research, and that the small amount of development activity performed (representing 4 percent of total R&D funding to universities and colleges) is closely tied to the growth of disciplinary knowledge. In nonacademic settings—where the distinction between research and nonresearch roles is clearer, and applied research is more closely tied to product development—"researcher" ap-

plies to anyone whose primary work activity is basic research.¹

Two kinds of data are available on researchers: figures for all researchers, regardless of degree level; and figures on doctorate-level researchers alone. Both types of data are used in this section, often in comparison with each other.

Number of Researchers

As mentioned in chapter 3, "Scientific and Engineering Workforce," more than 4 million scientists and engineers are employed in the United States in various occupations. Of the 1.2 million scientists and engineers in research or development (see appendix table 3-4), it is estimated that 213,300 were engaged in academic R&D or basic research as their primary work activity in 1986. (See appendix table 5-3.) Of these, 168,900 (79 percent) were employed by universities and colleges. The remaining 44,400 were engaged in basic research elsewhere, including 13,100 in industry, 17,200 in the Federal Government, and 9,400 in nonprofit institutions.² (See figure 5-2.) Less than one-half of these researchers held a doctorate degree.³ (See appendix table 5-4.)

The proportion of doctoral researchers supported by Federal funds has been shrinking steadily, dropping from 56.0 percent in 1977 to 49.1 percent in 1985. (See table 5-3.)⁴ The share receiving Federal support varies among employing institutions and S/E fields. Outside the Federal Government itself, the percent receiving Federal support is highest in nonprofit institutions (72 percent in 1985), and lowest in industry (14 percent).

¹The actual operational definitions used in compiling the tables for this section may vary from those described here. Such variations—specified in notes within the tables—are caused by varying characteristics of data bases used.

²State and local governments employed 3,100 scientists and engineers in basic research; 1,900 were employed in other institutions.

³Note that this figure includes graduate students employed at universities in a research capacity.

⁴Note that this table includes researchers whose primary or secondary work activity was basic or applied research. Thus the numbers are larger than those in appendix table 5-4.

Table 5-3. Ph.D. researchers,¹ by sector and Federal support status: 1977, 1981, and 1985

Sector of employment	1977		1981		1985	
	Number employed	Percent support	Number employed	Percent support	Number employed	Percent support
Total ²	113,255	56.0	136,945	53.4	145,918	49.1
4-year colleges and universities	91,851	54.6	108,340	52.4	118,210	47.8
Nonprofit	5,540	82.2	7,334	79.0	7,002	71.5
Industry	9,014	21.3	12,623	15.4	12,336	14.0
Federal Government	6,850	99.9	8,648	100.0	8,370	100.0

¹ "Researchers" are defined as those primarily or secondarily employed in basic or applied research.

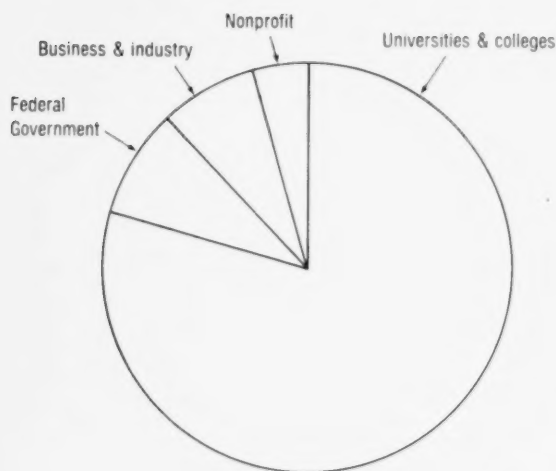
² Totals refer to these listed institution types only.

SOURCE: National Academy of Sciences, Survey of Doctorate Recipients, special tabulations

Science & Engineering Indicators—1987

Figure 5-2.

Scientists and engineers in academic research and development and basic research, by employment sector: 1986

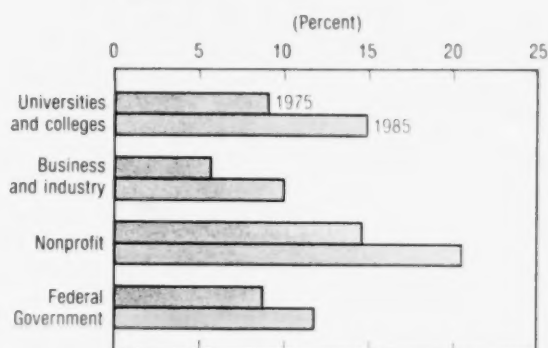


See appendix table 5-3

Science & Engineering Indicators — 1987

Figure 5-3.

Women as a percent of doctoral scientists and engineers in research, by type of employer:



See appendix table 5-5

Science & Engineering Indicators — 1987

Women Scientists and Engineers

The number of women with S/E Ph.D.'s in research has grown more slowly than the number in other S/E work activities. (See figure 5-3.) Nonetheless, the number of doctoral women in academic R&D and basic research nearly doubled between 1975 and 1985, and their proportion of all doctoral researchers rose from 9 percent to 15 percent during this time.

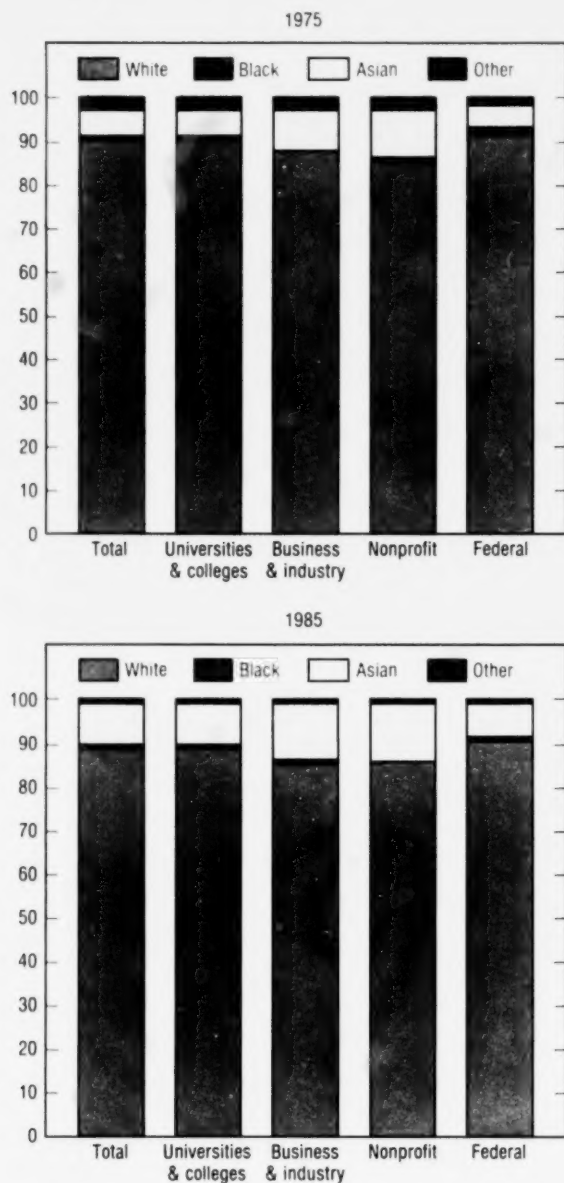
Minority Scientists and Engineers

The number of blacks with S/E doctorates in academic R&D and basic research also nearly doubled between

1975 and 1985, and the percentage of blacks increased from 0.78 to 1.16. (See figure 5-4.) Blacks as a percentage of the total workforce in basic research in industry more than doubled. However, since black enrollment in science and engineering degree programs has slowed in recent years (see chapter 2, "Higher Education for Scientists and Engineers"), future gains are not likely to be as dramatic. Moreover, black participation in research is still low compared with the percentage of blacks in the total S/E population. (See figure O-14 in Overview.) In contrast, between 1975 and 1985, the percentage of doctoral Asians in research increased from 5.7 to 9.0; this percentage is higher than their representation among the total population of scientists and engineers.

Figure 5-4.

Doctoral S/E's in research, by race and employment sector: 1975, 1985



See appendix table 5-6.

Science & Engineering Indicators — 1987

Postdoctoral Positions

Postdoctoral positions are increasingly important as a first step in a research career. Between 1979 and 1985, the number of postdoctoral positions in all fields of science at doctorate-granting institutions grew at an average annual rate of 3.9 percent. At 4.8 percent, the 1984/5 increase was larger than average, bringing the total number of

postdoctoral positions to 22,691. About two-thirds of these positions (15,264) were in the life sciences; another 20 percent were in the physical sciences. The number of positions increased most rapidly in the life sciences, which averaged a 4.6-percent increase per year between 1979 and 1985.*

Postdoctoral positions at U.S. institutions are attractive to foreign recipients of the U.S. doctoral degrees in S/E fields. Between 1972 and 1986, the number of foreign recipients of U.S. doctoral degrees who indicated firm plans to engage in further study at a U.S. institution increased threefold—from 251 to 744 individuals. In 1986, 28 percent of new foreign doctorate holders with firm plans indicated that they planned a period of postdoctoral study in the U.S. This was more than one-half (54 percent) of all those who planned to stay in the U.S. (See appendix table 5-7.)

Retention Rates in Research Careers

The extent to which doctoral scientists and engineers either stay in research careers or move into other activities is an indicator of the research workforce's stability. Retention rates for careers in basic and applied research have in fact been on the increase since 1975. The percent of those who remained in these activities over the preceding 2-year period was somewhat higher in 1985 than it was in 1975. This was particularly true among engineers. (See table 5-4.) However, engineers showed greater year-to-year variability than did scientists. Over the past decade, scientists leaving research have been moving less often into teaching and management activities, and slightly more often into development. Between 1983 and 1985, development was the most common destination for engineers leaving research; teaching was the least frequent choice. (See appendix table 5-31.)

Employment Sectors

In 1986, 79 percent of S/E researchers were employed at universities and colleges. (See figure 5-2.) This propor-

*See National Science Foundation (1987a), Table C-46.

Table 5-4. Retention rates for research¹ careers: 1973/75-1983/85

Years	All fields	Percent ²	
		Scientists	Engineers
1973-75	72.2	74.2	60.1
1975-77	70.9	72.8	59.4
1977-79	63.9	67	45.7
1979-81	75.7	77.3	63.6
1981-83	72.9	75.3	59.1
1983-85	75.6	76.5	69.8

¹ Research is defined as primary work activity in basic or applied research

² Percent remaining in research over the preceding two-year period.

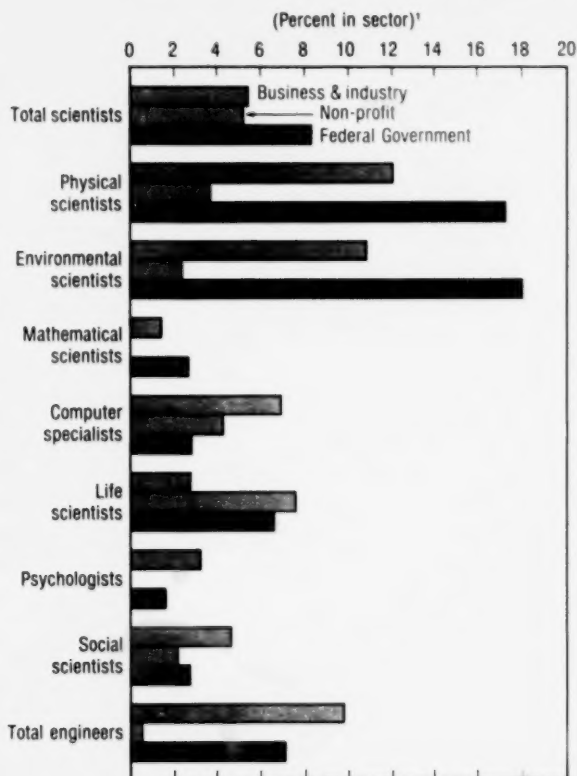
SOURCE: National Academy of Sciences, Doctorate Records File, special tabulations

Science & Engineering Indicators—1987

tion was nearly identical for both doctorate holders and other scientists and engineers. Some fields, however, have a higher representation of basic researchers outside the academic sector. (See figures 5-5 and 5-6.) For instance, 12 percent of all physical science researchers (and 21 percent of those with doctorates) work in industry; in contrast, industry employs only 5 percent of science researchers in all fields. Similarly, 17 percent of researchers in chemistry (30 percent of doctoral chemists) are employed in industry. Relatively large shares of earth scientists and computer specialists also work in industrial research. Environmental scientists are more likely to work for either a nonprofit institution or the Federal Government than are scientists in other fields.

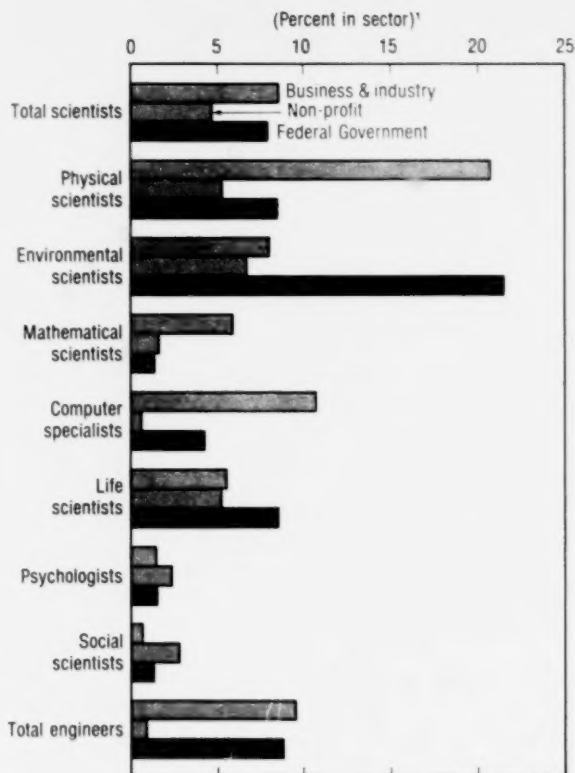
Engineering researchers are nearly twice as likely as scientists to work in the industrial sector. Among engineers, the Federal Government employs only 7 percent overall, but 37 percent of aeronautical and astronautical engineers (34 percent of those at the doctoral level), and 20 percent of materials engineers with doctorates. In engineering, the fields of concentration in industry and

Figure 5-5.
Non-academic scientists and engineers in basic research, by sector and field: 1986



¹Percentage of all scientists and engineers in academic R&D and basic research.
See appendix table 5-3. Science & Engineering Indicators — 1987

Figure 5-6.
Non-academic doctoral scientists and engineers in basic research, by sector and field: 1985



¹Percentage of all doctoral scientists and engineers in academic R&D and basic research.
See appendix table 5-4. Science & Engineering Indicators — 1987

government are similar; in science, fields of concentration differ between industry and government.

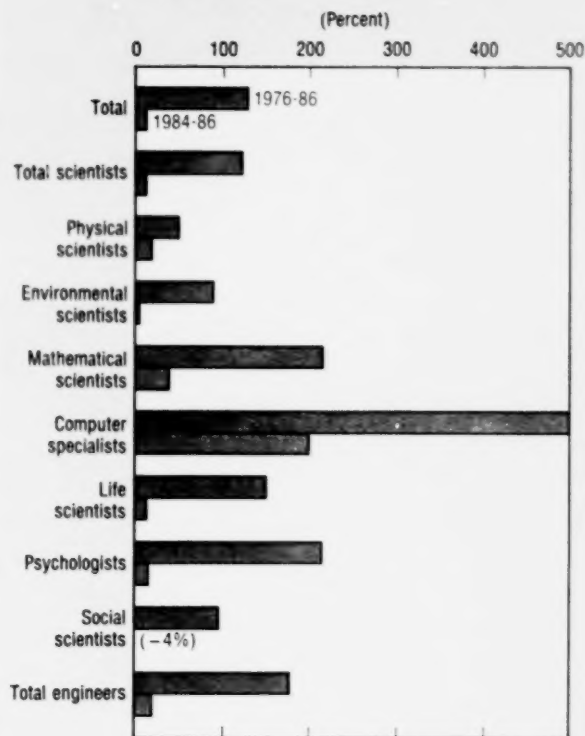
Growth Patterns by Field

Over the last decade, the total number of scientists and engineers in academic R&D and basic research has more than doubled, and the number of doctorate holders has increased by 40 percent. (See figures 5-7 and 5-8.) Research engineers have increased faster than have research scientists (178 percent and 122 percent increases, respectively). At the doctorate level, the increases were 53 percent for engineers and 39 percent for scientists.

Among research scientists, computer specialists¹ are the fastest growing group, increasing fivefold between 1976 and 1986 (184 percent at the doctorate level). Since the number of computer specialists is still relatively

¹Computer specialists are included among the fields of science rather than engineering.

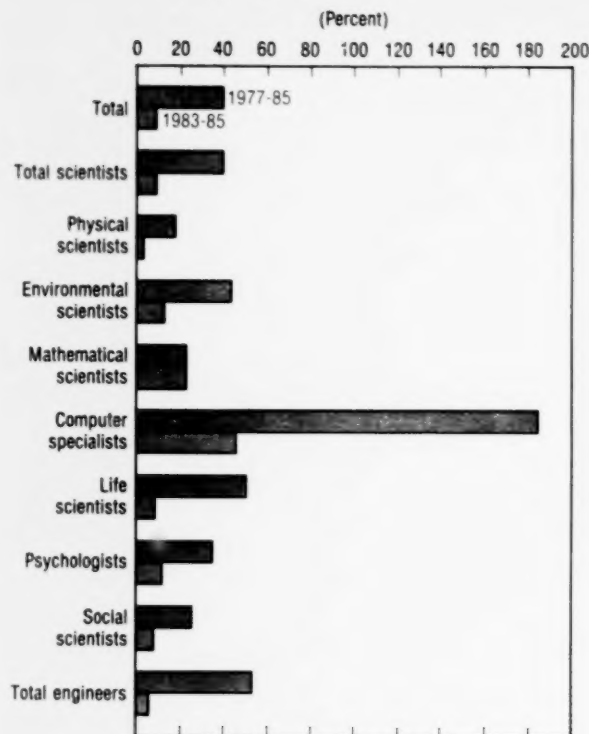
Figure 5-7.
Growth of S/E's in academic R&D and basic research, by field



See appendix table 5-9.

Science & Engineering Indicators — 1987

Figure 5-8.
Growth of Ph.D. S/E's in academic R&D and basic research, by field



See appendix table 5-10.

Science & Engineering Indicators — 1987

small, however, this growth is not a major factor in the overall increase in scientists performing academic R&D and basic research. Researchers in the physical sciences show the lowest growth rates of any major disciplinary group for the decade: 18 percent overall and 26 percent at the doctorate level.

In the most recent 2-year period,¹⁰ growth in the number of engineers in academic R&D and basic research was greater than that of scientists (19 percent versus 12 percent). At the doctorate level, however, the increase among engineers was less than among scientists (5.5 percent versus 8.9 percent). Chemical, industrial, and electrical/electronics engineers increased fastest—50 percent, 40 percent, and 29 percent, respectively, in total numbers. Among doctoral research engineers, mechanical, chemical, and civil engineering showed the fastest growth—98 percent, 39 percent, and 23 percent, respectively. Materials engineers in research decreased by 25 percent. In the most recent 2-year period, the total

number of computer specialists engaged in research expanded by 20 percent (46 percent at the doctorate level).

CROSS-SECTOR INTERACTIONS

An important measure of the strength of the U.S. research system is the extent of interaction among the various research-performing organizations—particularly between scientists and engineers in academia and those basic researchers in more mission-oriented sectors. Indicators of this interaction include mobility of researchers, coauthorship across sectoral lines, and citations among sectors. The following describes these indicators, and then discusses university-industry interactions.

Cross-Sector Mobility of Researchers

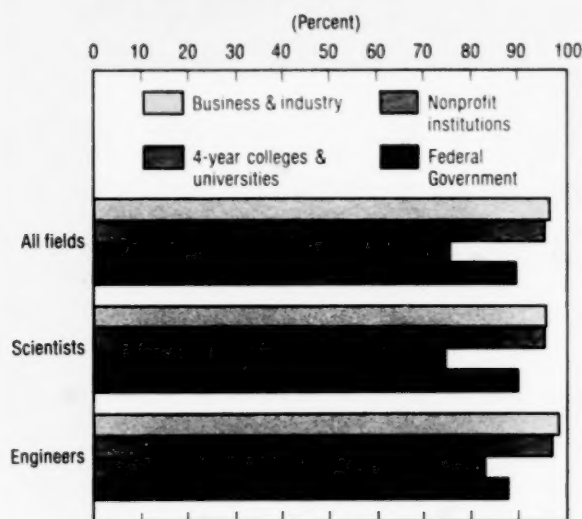
People are the principal carriers of ideas from one setting to another. The 2-year mobility rates shown in appendix tables 5-8, 5-11, and 5-12 indicate the flow of people among research-performing organizations. In general, over any given 2-year period, most scientists

¹⁰Alternate year surveys were conducted of all scientists and engineers and S/E Ph.D.'s. Data for these two groups thus refer to the periods 1984-86 and 1983-85, respectively.

and engineers do not change their sectors of employment. (Note the estimated stability rates in figure 5-9.) For example, about 95 percent of researchers in either private industry or academia were still working in their respective sectors 2 years later. This level of stability has been about the same for the last decade. Among government researchers, the stability rate rose between 1973 and 1975 and between 1981 and 1983, but dropped between 1983 and 1985. Government researchers who change sectors are most likely to go to academia: nearly 5 percent did so between 1983 and 1985. (See appendix table 5-11.)

Figure 5-9.

Percent of Ph.D. researchers who remained employed in the sector between 1983 and 1985



See appendix table 5-8.

Science & Engineering Indicators — 1987

Researchers in nonprofit organizations are most likely to move into another sector, probably because their jobs are most vulnerable to shifts in funding. In the past decade, about one-fourth of the researchers in nonprofits moved to another sector over any given 2-year period. Moreover, in both 1973-75 and 1981-83—periods when nonprofit institution basic research spending decreased—the percentage of researchers moving to another sector rose to one-third. During those periods, engineers were more likely to leave the nonprofit sector than were scientists. In 1973-75, nonprofit researchers were most likely to move into academic positions. During this time, an estimated 22 percent moved into academic positions. This represented 21 percent of scientists and 25 percent of engineers. In 1981-83, they were more likely (18 percent) to move to positions in industry. (See appendix table 5-11.)

The migration rates for doctorate-level researchers between academia and industry are estimated to be small. (See appendix table 5-12.) Among scientists, a trend toward increasing proportions of academic researchers leaving for industry was reversed in 1983-85, when only 2.3 percent left for industry (compared with 2.8 percent between 1981 and 1983). On the other hand, the share of industry researchers moving to academia continued to climb, reaching 2.2 percent between 1983 and 1985.

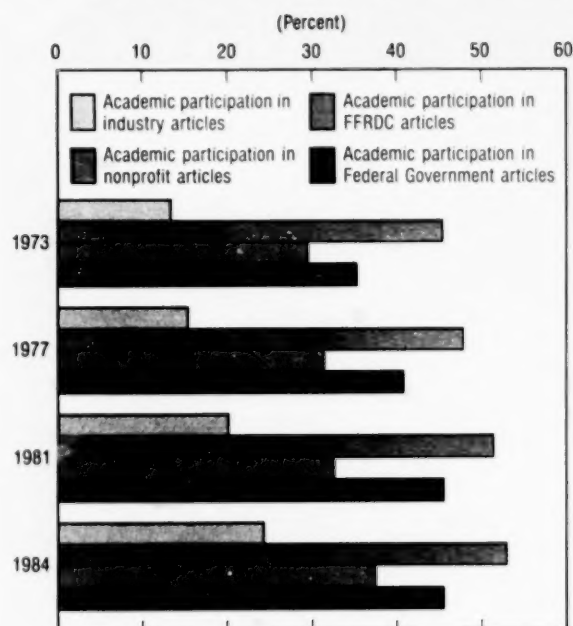
Rates for engineers are harder to estimate because the numbers are small. However, the rate of cross-mobility for engineers seems to have dropped in the latest time period, with 1.6 percent of academic researchers moving to industry and only a fraction of 1 percent of industry researchers moving to academia.

Cross-Sector Coauthorships and Citations

Research collaboration across sectors is on the rise, as indicated by the percent of U.S. publications with authors from more than one sector. (See appendix table 5-13 and figure 5-10.) Coauthorship rates in general are increasing across the fields of science and engineering (see figure 5-11), as are cross-sectoral coauthorships among all possible combinations of research-performing institutions. For instance, in 1973 only 19 percent of articles by authors in industry were coauthored with someone working in an-

Figure 5-10.

Percent of articles by authors working in different sectors which were coauthored by academic authors

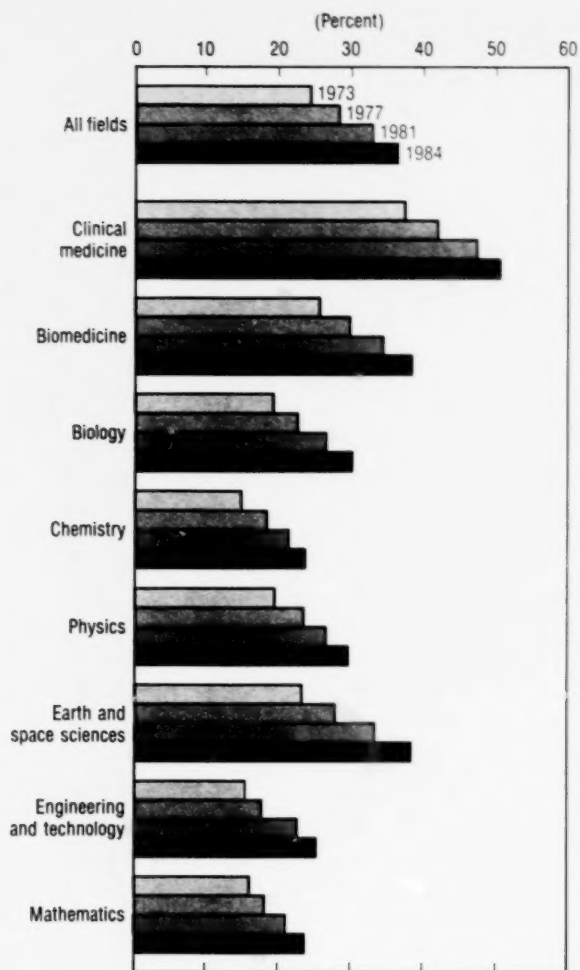


See appendix table 5-13.

Science & Engineering Indicators — 1987

Figure 5-11.

Coauthored articles as a percent of all articles, by field of science: 1973, 1977, 1981, 1984



See appendix table 4-36.

Science & Engineering Indicators — 1987

other sector. (See appendix table 5-13.) In 1984, however, 36 percent were coauthored across sectors. Twenty-four percent of industry articles were coauthored with university researchers. The fastest growing areas of industry-university coauthorships in this period were biology and biomedicine; this may well reflect the rapid growth in the commercial significance of biotechnology. (See figure O-32 in Overview and appendix table 5-15.) Industrial coauthorship with FFRDC's and government laboratories also rose sharply.

In contrast, or perhaps as a consequence, the attention shown by researchers in one sector to articles published in another (as indicated by citation rates) has been drop-

ping in most cases over the last decade. (See appendix table 5-14.) While the levels of citation from university authors to industrial authors remained relatively stable between 1973 and 1984, the attention given by industry to academia (using the citation indicator) dropped. The numbers show a significant increase in attention among nonprofit and Federal Government researchers toward articles from industry, as well as toward FFRDC's in the nonprofit case.

Examining the publications in detailed S/E fields illustrates the interdependence of research among the various sectors. For example, note the rapidly expanding research areas of transition-metal silicides and silicon molecular-beam epitaxy. Both of these areas are of strategic importance for the United States: the Soviet Union and Japan have active research efforts in each. Moreover, in each, the most active U.S. institutions are from different sectors. In transition-metal silicides, the most active institutions in 1984 were Bell Laboratories, IBM, RCA, the California Institute of Technology, and Stanford University. The most active institutions in 1984 in silicon molecular-beam epitaxy were Bell Laboratories, the Massachusetts Institute of Technology, the State University of New York at Albany, and the University of California at Los Angeles.¹¹

University-Industry Contacts

Concern with the international competitive position of U.S. industry has focused attention in particular on university-industry contacts. As noted in chapter 4, "Resources for R&D and Basic Research," industry support is the fastest growing source of support for university research, although it is still a small percentage of the total. These data, along with information on coauthorship and cross-citation, suggest that the level of contact between industry and academia may be increasing.

Research itself is only one reason for university-industry contact. Educational ties may be more important in the long run. In a 1984 survey, a large share of doctorate-granting institutions reported research ties with industry (91 percent of public and 65 percent of private), but among all the institutions responding, only 18 percent reported research contacts.¹² The most widespread ties were joint meetings and equipment sharing (reported by more than 70 percent of responding campuses), followed by direct educational contacts: scholarship/loan programs and credit and noncredit courses for employees. (Between 40 and 50 percent of responding campuses were involved in these.) Lastly, 15 to 20 percent of universities reported jointly sponsored degree programs, shared staff arrangements, or research contacts.

A similar survey among firms in Michigan produced the distribution of contacts noted in appendix tables 5-16 and 5-17. Attending conferences appears as the most frequent form of contact (as it did in the survey among universities), and research contracts involved only a

¹¹Unpublished data provided by the National Science Foundation, Division of International Programs.

¹²American Council on Education (1985).

small proportion of the firms. In general, the larger the company, the greater its range of university relations. Also, university-industry interaction is related to company life cycles. Companies at the start-up stage were most likely to use technical services, employ faculty consultants, and have a variety of other professional interactions with nearby campuses. Companies at the stage of rapid growth were most likely to recruit graduates, sponsor internships, and send staff to conferences. Companies of stable or declining growth had the lowest levels of university interaction.¹³

Numerous and varied Federal programs have tried to encourage university-industry interaction over the years.¹⁴ In the 1980's, many States also initiated efforts to encourage contacts between local universities and industrial firms. Much of the encouragement is for educational activities of the sort mentioned above, but some of the efforts are focused on research. Surveys by the National Governors' Association and the U.S. Congress, Office of Technology Assessment, identified about 50 of these efforts, spread across 29 States.¹⁵ More than two-thirds of the research initiatives consisted of matching grants for industrial funding of university research, sometimes involving collaborative work. Cumulative 1980-84 funding in these programs was estimated at \$350-450 million.

Faculty Consulting. Academic R&D contributes to industrial innovation through direct transfer of information in the form of technical services and formal or informal consulting relationships. An estimated 80 percent of faculty members at U.S. universities and colleges have consulted for an off-campus client at some point in their careers, although less than 20 percent report having done "a great deal" of it.¹⁶ About 90 percent of engineers have had such experience; at less than 70 percent, mathematicians and statisticians are least likely to have had this experience. Every type of campus is involved. About three-fourths of the faculty at baccalaureate institutions report consulting experience, ranging up to nearly 90 percent of those at select research institutions.

There is a special relationship between small businesses and teaching institutions. In a 1984 survey, faculty at comprehensive universities, colleges, and baccalaureate institutions were much more likely to report that their last clients were small businesses than were researchers at research universities or engineering schools. These discrepancies are particularly great in the environmental sciences. (See appendix table 5-18.)

Research Contacts. The distribution of industry support among fields of academic science is not known; about one-half, however, is apparently spent in engineering.¹⁷

In a 1984 survey, industry respondents ranked the relevance of research in the various science fields to technical change in their lines of business. Computer science and metallurgy headed the list, followed by materials science and chemistry.¹⁸

Industrial support of university research in biotechnology has received considerable attention in recent years, but a 1985 survey shows that this support has not yet reached the relative importance that it has in chemistry and engineering.¹⁹ Twenty-three percent of respondents working in the "new biotechnologies" were principal investigators on projects sponsored by industry, as compared with 43 percent of those in chemistry and engineering. Industry supplied 7.4 percent of the research funds received by biotechnology faculty, as compared with 32 percent of the funds received by chemistry and engineering faculty.

University Entrepreneurship. Another new feature of the relationship between universities and commerce is academic entrepreneurship, which involves both individual faculty members and universities themselves. Several developments have influenced this trend, including changes in Federal patent laws and the emergence of the biotechnology industry.

In 1980, Federal patent law was altered to allow universities and small businesses to retain title to inventions resulting from Federally sponsored research projects. This change provided a new incentive for the formation of businesses based on university inventions. The effects of this change in the law are expected to appear only in the long term; further, they will be difficult to separate from other changes in the academic environment.²⁰

The level of patenting activity of U.S. universities and colleges has increased over the past 2 decades (see appendix table 5-19), although academic patenting remains only a small share of the total. The rate of increase in patents granted between 1980 and 1985 was more than double the rate of increase in the preceding 5 years; it was somewhat less, however, than the rate of increase for 1970-75. The most active patent classes are in the biomedical area: bio-affecting drugs, molecular biology and microbiology, and surgical inventions.

Another sign of the involvement of academia in the commercial sphere is the appearance of spin-off firms founded by university scientists. Despite the attention devoted to a few examples such as Cetus and Genentech, there are indications that this phenomenon is concentrated in a few universities and involves only a handful of firms.²¹ A 1985 survey found that only 8 percent of faculty in biotechnology fields held equity in a company whose products or services were based on their research.²² Similarly, a study of the "Cambridge phenomenon" has

¹³Pelz and Hart (1986).

¹⁴For a description of the National Science Foundation's array of programs in this area, see Bloch and Kruytbosch (1986), pp. 51-57.

¹⁵National Governors' Association (1983) and (1985); and U.S. Congress, Office of Technology Assessment (1983) and (1984). In extracting State-sponsored research programs from these documents, research was defined as the advancement of knowledge. Basic and applied research were included, as were those small amounts of development funding that could not be separated from research.

¹⁶Darknell and Nasatir (1987).

¹⁷Engineering Education (1987).

¹⁸Nelson (1986), p. 187.

¹⁹Blumenthal, et al. (1986), p. 1362.

²⁰A study of university patenting policies before and after the change in the law was conducted by the Society of University Patent Administrators. A copy of the report is available from Frederic H. Erbsch, Director of Research Services, Michigan Technological University, Houghton, MI 49931.

²¹Peters and Fusfield (1983).

²²Blumenthal, et al. (1986), 1364.

shown that most of the high-technology development associated with that university town has been generated through a chain of spin-offs from firms, not by spin-offs directly from the university.²³

INTERNATIONAL CONTACTS

Science and engineering research has always been an international activity. For centuries, students have traveled to the world's scientific centers for training and maintained contact with their teachers after returning home. There is an equally strong tradition of researchers with common interests collaborating across national boundaries. Scientific knowledge, once created, has been shared. The following presents indicators of U.S. participation in the international world of science.

The evidence presented here points to a changing pattern. The U.S. educational system is granting an increasing number of doctorate degrees to foreign nationals, and larger proportions of these degree recipients are electing to stay in the U.S. to pursue their careers. At the same time, U.S. citizens with new doctoral degrees are going abroad at the same rates as for the past decade. At the senior level, U.S. researchers are collaborating more internationally. Yet world science is paying somewhat less attention to U.S. science (at least as indicated by citations) than it has in the recent past.

Young Researchers

In 1986, a larger share of doctorate recipients in the United States were foreign citizens than at any time in the last 10 years, and a larger share of them had plans to stay and work in the United States. In 1975, 16 percent of doctorate recipients were foreign nationals, as compared with 21 percent in 1986. (See appendix table 5-20.) Of those with firm postgraduation plans, 29 percent in 1972 planned to stay in the United States, but 52 percent planned to do so in 1986. (See appendix table 5-7.) Of this latter group, 54 percent were staying for postdoctoral research, 26 percent for academic employment, and 17 percent for industrial employment. In the physical and biological sciences, the largest percentages were staying for postdoctoral study; in engineering, mathematics, and computer science, the largest percentages were going directly into academic or industrial employment.

One-half as many S/E doctorate recipients who were U.S. citizens (214) planned to go abroad for postdoctoral study in 1983 as the number of foreign recipients who planned to stay here (434). (See appendix table 5-21.) The percentage of U.S. citizens going abroad for postdoctoral study has fluctuated over the years. It reached its high point in 1971, when 2.4 percent went abroad. In recent years, the share has been much lower, about 1.5 percent. In psychology, the trend has clearly been down; in other fields, such as agriculture and the social sciences, the share seems to be rising.

International Collaboration

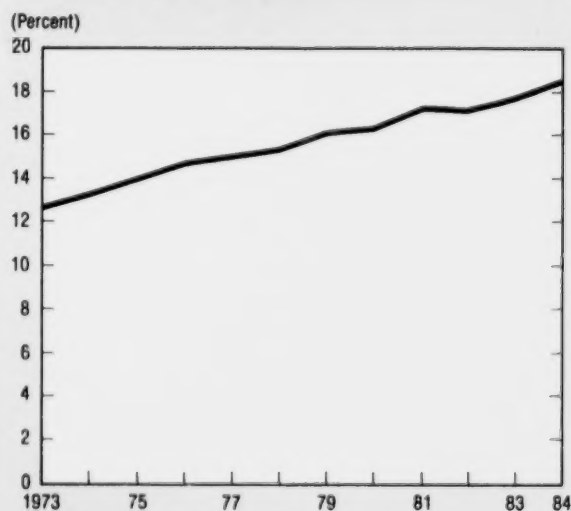
International collaboration is playing an increasingly large role in the production of scientific knowledge. One sign of this trend is the increase in academic exchange visas granted by the U.S. Government. In 1986, 102,854 foreign nationals were granted visas to visit universities in the United States; this was up 15 percent over 1985, and up 52 percent since 1978. (See appendix table 5-22.)

This is also demonstrated by cross-national coauthorships in the research literature. U.S. articles that were internationally coauthored have made up a larger share of the literature every year over the past decade. (See figure 5-12.) In 1984, 18 percent of papers with authors from more than one institution involved international collaboration, as compared with 13 percent in 1973. International collaboration increased fastest in the fields of engineering and technology (a 58-percent increase in the share from 1973 to 1984) and physics (a 48-percent increase). (See appendix table 5-23.) Researchers at FFRDC's were most likely to be involved in international coauthorship in 1984, followed by those in universities and industry. (See appendix table 5-24.) More than 25 percent of publications from FFRDC's were internationally coauthored, as compared with 18 percent for private firms and 16 percent for universities. Industry's cross-national collaboration rate is increasing more slowly than the rates in other sectors.

The increase in U.S. international collaboration has been modest compared with that in other major scientific

Figure 5-12.

Internationally coauthored articles as a percent of all institutionally coauthored articles¹



¹Based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information. The last four years use over 3,500 journals of the 1981 Science Citation Index Corporate Tapes. See appendix table 5-23.

Science & Engineering Indicators — 1987

²³The Cambridge Phenomenon (1985).

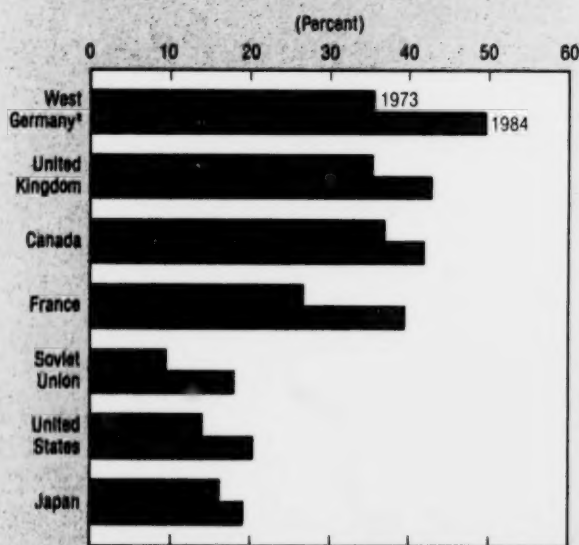
nations; further, the U.S. level of international collaboration is relatively low. (See figure 5-13.) In West Germany, the United Kingdom, France, and Canada, from one-third to one-half of institutionally coauthored publications are coauthored with researchers from other nations, as compared with about one-fifth in the United States. The U.S. percentage is similar to that for the U.S.S.R. and Japan.

Publications

The share of the world's literature that comes from the United States has been stable for some time at 35 percent,²⁴ as have the U.S. shares of world publications in the various S/E fields. The fields in which the U.S. produces the largest share of the world's publications are earth and space sciences (41 percent), clinical medicine (41 percent), engineering and technology (40 percent), and biomedicine (39 percent). (See appendix table 5-26.) The distribution of articles by subfield appears in appendix table 5-27.

²⁴The slight drop in the percentage between 1980 and 1981 is the result of an enlargement of the data base.

Figure 5-13.
Internationally coauthored articles as a percent of all institutionally coauthored articles, by country¹



¹The 1973 data are based on articles, notes, and reviews in over 2,100 influential journals carried on the Corporate Tapes of the 1973 Science Citation Index of the Institute of Scientific Information. The 1984 data are based on over 3,500 journals in the 1981 Science Citation Index.

²When an article is authored by scientists and engineers from more than one country, that article is counted once for each country involved.

See appendix table 5-25.

Science & Engineering Indicators -- 1987

Cross-National Attention

While international collaboration in the form of coauthored papers is increasing, a closer look at the literature indicators suggests two further developments in the flow of information between U.S. and foreign researchers.

First, U.S. authors are paying increasing attention to the published work of foreign authors. Between 1974 and 1984, references in U.S.-authored S/E articles to foreign-authored articles increased from 23 percent to more than 29 percent of all references. (See figure O-21 in Overview and appendix table 5-28.) This pattern holds across all broad S/E fields. It is most marked in mathematics, where the proportion of references to foreign articles almost doubled over the decade.

Second, while U.S. researchers are increasingly scanning foreign literatures, world S/E authors are paying slightly less attention to U.S. published work. (See appendix table 5-29.) The U.S. literature published in 1982 was cited only about 83 percent as frequently as one would expect on the basis of its volume—down from 96 percent in 1980.²⁵ U.S. physics, chemistry, and earth and space sciences received the most attention from abroad, more than 90 percent of what would be expected based on the volume of the 1982 published literature.

A Case Study in International Collaboration

The earth and space sciences illustrate the trends toward internationalization outlined above. These fields also show the growing levels of international activity as demonstrated by shared facilities—for example, those provided by the Deep Sea Drilling Project (DSDP), the world's largest international collaborative venture.

Both institutional and international coauthorship have been rising in the earth sciences. Institutional coauthorship rose from 23 percent of all articles in 1973 to 39 percent in 1984. (See appendix table 4-36.) Internationally coauthored articles have risen from 23 percent of all institutionally coauthored articles in 1973 to 34 percent in 1984. (See appendix table 5-23.) Among the nine most active nations in these fields, the U.S. shows the second highest level of in-country institutional coauthorship. (The highest level is in the Soviet Union.) The U.S., however, is also the most frequent partner of the other active countries when they coauthor internationally.²⁶

One factor contributing to the increase in international coauthorship in these fields is the need to share very expensive research equipment. For instance, special drilling ships and equipment are needed to drill into the ocean floor and retrieve geological information. In 1974,

²⁵Although this measure of world attention to the 1982 U.S. literature can be expected to rise somewhat when 1985 and 1986 citing literature are added to the data base, it is still lower than the comparable figure for the 1980 literature (that is, the relative citation ratio—85—for the 1980 literature as cited by only 1981 and 1982 papers).

²⁶Computer Horizons, Inc. (1986).

the National Science Foundation's ocean drilling program—which operated such a ship—was internationalized. The \$40 million annual operating costs of the new Deep Sea Drilling Project are now shared among six partner countries, including the United Kingdom, West Germany, Canada, Japan, and France. Scientists from member countries propose shipboard projects to a selection panel, and share the ship and its facilities on its research voyages.

Areas of research in which DSDP results are reported show higher levels of international coauthorship than appear in the earth sciences as a whole. The 10 areas listed in appendix table 5-30 were identified in a bibliometric data base as some of the ones where results of

DSDP projects are most prominent.²⁷ U.S. authors publishing in these areas showed noticeably higher rates of international coauthorship in 1983 and 1985 than the rates for the earth sciences as a whole in 1982. These data are consistent with the notion that the activities of the Drilling Project itself encourage international collaboration.

²⁷The areas of research were created through co-citation clustering of the *Science Citation Index*. Areas where the term "deep sea drilling" appeared frequently in article titles were chosen for analysis. The set of research areas is thus intended to illustrate the collaboration rates in DSDP research areas, and not to be either comprehensive or representative.

REFERENCES

- American Council on Education, "Campuses Weld the Corporate Link," *Educational Record*, Spring 1985.
- Bloch, E. and C. Kruytbosch, "The NSF Role in Fostering University-Industry Research Relationships," *IEEE Transactions on Education*, Vol. E29, May 1986.
- Blumenthal, D., et al., "University-Industry Research Relationships in Biotechnology: Implications for the University," *Science*, 232, June 13, 1986.
- The Cambridge Phenomenon: The Growth of High Technology Industry in a University Town* (Cambridge, England: Segal Quince Wicksteed, 1985).
- Computer Horizons, Inc., *Science Indicators Literature Data Base, Indicator Series #6: International Coauthorship* (data base prepared under contract to the National Science Foundation, 1986).
- Darknell F. and D. Nasatir, "Consulting as a Science Indicator," final report to the National Science Foundation under Grant SRS-8307778, May 1987.
- Engineering Education*, special issue, "Engineering College Research and Graduate Study," Vol. 77, No. 6, March 1987.
- National Governors' Association, *Programs for Innovative Technology Research in State Strategies for Economic Development* (Washington, DC: December 1985).
- National Governors' Association, "Technology and Growth: State Initiatives in Technological Innovation," final report of the Task Force on Technological Innovation (Washington, DC: October 1983).
- National Science Foundation, "Academic Science/Engineering: Graduate Enrollment and Support, Fall 1985," SRS 87-D5 (Washington, DC: National Science Foundation, 1987a).
- National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1985, 1986, 1987, Volume XXXV* (Washington, DC: National Science Foundation, 1986).
- National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1986, 1987, 1988, Volume XXXVI* (Washington, DC: National Science Foundation, 1987b).
- National Science Foundation, *Research and Development in Industry* (Washington, DC: National Science Foundation, 1984).
- Nelson, R.R., "Institutions Supporting Technical Advance in Industry," *American Economic Review*, Vol. 76, No. 2, May 1986.
- Pelz, D.C., and S.L. Hart, "Business Firm Study: Basic Data on Relations with Universities" (Ann Arbor: University of Michigan, 1986).
- Peters, L. and H.I. Fufeld, "Current U.S. University-Industry Research Connections," in National Science Board, *University-Industry Research Relationships: Selected Studies*, NSB 82-2 (Washington, DC: National Science Foundation, 1983).
- U.S. Congress, Office of Technology Assessment, *Technology, Innovation, and Regional Economic Development: Encouraging High Technology Development—Background Paper #2*, OTA-BP-STI-25 (Washington, DC: February 1984).
- U.S. Congress, Office of Technology Assessment, *Technology, Innovation and Regional Economic Development Background Papers: Census of State Government Initiatives for High Technology Industrial Development*, OTA-BP-STU-21 (Washington, DC: May 1983).

Chapter 6

Industrial Research and Technological Innovation

Industrial Research and Technological Innovation

HIGHLIGHTS

- *Industry employs about four-fifths of all engineers in the United States and one-half of all scientists.* This includes more than three-quarters of all computer specialists and more than one-half of all environmental scientists. From 1976 to 1986, employment of industrial scientists and engineers increased by 8 percent per year, in spite of a major recession during this period. (See pp. 103-104.)
- *Expenditures for industrial research and development (R&D) are growing.* Total industrial expenditures for R&D are estimated at \$91 billion for 1987; this represents 73 percent of all R&D expenditures in the United States. From 1980 to 1987, the average annual increase in industrial R&D expenditures was 5.8 percent in constant dollars. (See p. 104.)
- *Private industry has funded more than one-half of all industrial R&D every year since 1968, and now funds nearly two-thirds of the total.* From 1980 to 1985, the annual rate of increase in company R&D spending was 5.5 percent in constant dollars. Only a 3-percent increase is estimated from 1985 to 1986, and a 2-percent increase from 1986 to 1987. (See pp. 104-105.)
- *The rate of increase of Federal funds for industrial R&D has slowed after a period of rapid growth.* From 1980 to 1985, Federal funds for industrial R&D rose at an annual rate of 7.8 percent in constant dollars. The estimated increase for 1985 to 1986 is 14 percent; however, for 1986 to 1987, the estimated rate of increase dropped to 3 percent. (See p. 105.)
- *As a group, nonmanufacturing industries that perform R&D showed considerable employment growth from 1975 to 1985.* During this time, employment rose only slightly in high-technology manufacturing. Employment declined in other manufacturing. (See pp. 105-106.)
- *Between 1980 and 1985, R&D expenditures increased especially rapidly in high-technology manufacturing industries.* The growth rate was 7.6 percent per year in constant dollars, compared with 2.4 percent per year in other manufacturing and 3.9 percent per year in non-manufacturing. This increase in high-technology spending was largely due to Federal expenditures for defense R&D in the aircraft and missiles industry. Such expenditures grew annually by 9.3 percent in constant dollars during this period. (See p. 106.)
- *The decline in patenting by Americans has stopped, but foreign patents in the U.S. continue to increase.* The filing of successful patent applications by Americans peaked in 1969 and reached a low point in 1983, with a slight (14 percent) recovery from 1983 to 1986. Small companies receive about 12 percent of U.S. domestic patents; universities receive about 2 percent. Successful patent applications by foreigners have increased, currently accounting for 46 percent of all U.S. patents. (See pp. 106-108.)
- *Japanese patenting in the United States has increased considerably in recent years, especially in high-technology fields.* From 1975 to 1986, the Japanese share of U.S. patent grants increased from 8 to 19 percent. This increase offset the drop in the American share, particularly in the transportation equipment and office, computing, and accounting machine fields. In a sample of 13 narrow high-technology fields, the number of Japanese patents increased in all fields, and the Japanese share increased in all but one. Furthermore, although the number of American patents increased in 7 fields, the American share decreased in all 13 fields. (See pp. 108-110.)
- *Small high-technology businesses have experienced a much higher rate of growth during the last decade than has either small business employment overall or total employment.* In some high-technology industries, there was a strong trend for successful small firms to leave the pool of small businesses, either through internal growth, merger, acquisition, or corporate takeover. Consequently, firms representing 16 percent of small business employment in 1980 in the office, computing, and accounting machine industry had become parts of medium-sized or large firms by 1984. (See pp. 111-114.)
- *The pool of capital managed by venture capital firms was almost seven times as large in 1986 as it was in 1978.* Venture capital is an important source of funds in the expansion of small high-technology companies. In 1986, new funds made available to venture capitalists reached \$4.5 billion. Throughout the early 1980's, disbursements by venture capitalists lagged behind new commitments of funds, indicating a growth of the capital still available for investment. Firms producing computers and computer-related goods and services have been popular with venture capitalists, both for direct venture capital investments and for venture-backed offerings of stock. (See pp. 114-115.)
- *Small business has been particularly important in the biotechnology industry.* Approximately two-thirds of the firms reporting activity in biotechnology employed fewer than 1,000 people; about 75 percent of these were privately held firms. These firms were concentrated in genetic engineering and in biotechnology equipment. There are preliminary indications that new firms entering the biotechnology field are shifting from the core areas of genetic engineering and immunology to such specializations as equipment, cell culture technologies, and animal biotechnology. (See pp. 115-116.)

In the United States, as in many other Western countries, private industry is the source of technological innovation and the site of most R&D activity aimed at such innovation. This sector is also the principal employer of scientists and engineers.

In terms of expenditures, private industry performs about 73 percent of the Nation's R&D. (See figure 6-1.) In the other four large free-market countries (Japan, West Germany, France, and the United Kingdom), industry's share of the total national R&D is lower; however, that in Japan and West Germany is beginning to approach the U.S. level. As a source of funds, private industry supports about one-half of all R&D conducted in the United States. (See figure 6-1.) While this is a high level, it is exceeded by countries like West Germany and Japan that do not have such large amounts of government-supported military R&D.

Current U.S. policy interest is centered on sustaining economic growth, and especially on fostering the international competitiveness of U.S. industries in both high- and low-technology areas. Industrial competitiveness affects such broad economic issues as job creation and retention, the rate of inflation, the balance of payments, and economic growth. Federal policy attempts to encourage industrial growth and competitiveness in several ways. It seeks to promote technological development through direct support and tax incentives for R&D expenditures, and through measures to control inflation, improve capital formation, improve the patent system, and remove unnecessary Federal regulations. Thus, Federal support for basic research—principally at universities and colleges, but also at agricultural experiment stations, hospitals, and Federal and private laborato-

ries—supplies part of the knowledge base for new technology. Support for science and engineering (S/E) education provides the necessary personnel, again primarily by way of the university and college sector. Finally, regulatory and patenting reforms are intended to improve the conditions and incentives for increased industrial science and technology (S/T) activities.

This chapter discusses indicators of recent trends in industrial S/T resources and activities related to technological innovation. "Input" indicators such as S/E personnel, R&D expenditures, and venture capital outlays are presented. This is followed by discussions of trends in patenting, the role of small business in innovation, and selected measures of technological innovation.¹

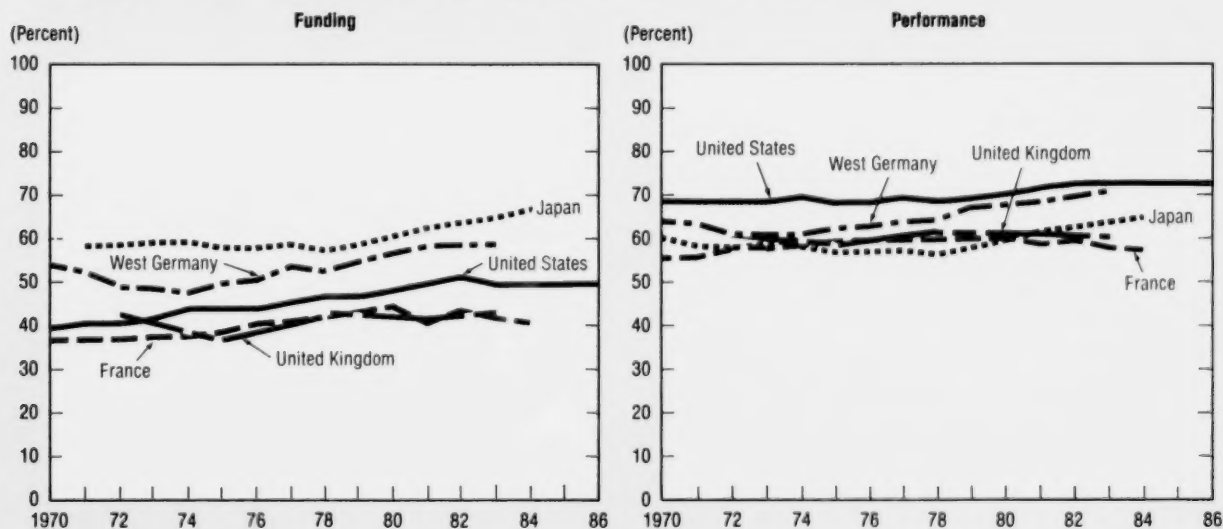
SCIENTIFIC AND ENGINEERING PERSONNEL IN INDUSTRY

The past decade has seen dramatic changes in the occupational and industrial distribution of the science, engineering, and technical workforce in industry. (See chapter 3, "Science and Engineering Workforce," pp. 55-58.) The principal broad features of these changes are: (1) the rapid expansion of the nonmanufacturing sector which primarily accounted for the increase in S/E employment during the decade; and (2) the increasing proportion of scientists and engineers in the relatively static

¹See also chapter 7, "The International Markets for U.S. Technology," for additional information on the competitiveness issue.

Figure 6-1.

Industry funding and performance of R&D, as a percent of total R&D, in selected countries



See appendix table 6-1.

Science & Engineering Indicators — 1987

total employment growth in the manufacturing industries, reflecting an increasingly "hi-tech" workforce in this sector.

Industry employs about four-fifths of all engineers in the United States, and about one-half of all scientists.² More than three-quarters of all computer specialists are in industry, as are three-fifths of physical scientists and more than one-half of all environmental scientists. R&D is the primary work activity of about one-fourth of all scientists and engineers in industry. While scientists are concentrated more in research than in development, the opposite is true for engineers. Many scientists and engineers also engage in other S/T-related activities, such as R&D management, teaching, design, testing, production, sales, and inspection. (See appendix table 3-4.) Thus, trends in industrial S/E employment reflect shifts in the amount and distribution of S/T-related work performed by industry.

Over the 1976-86 period, employment of scientists and engineers in industry grew—despite a major recession—at a rate of 7 percent per year. (See chapter 3, "Science and Engineering Workforce," p. 56.) This suggests not only that employment opportunities are increasing in science and engineering as compared with other fields, but also that industry is becoming more and more reliant on science and technology to improve its products, production processes, and services.

In 1986, industry employed almost 800,000 scientists and 1,800,000 engineers. Employment of scientists was dominated by computer specialists, while electrical/electronics and mechanical engineers were dominant among engineers. (See appendix table 3-16.) Since 1976, computer specialists have shown the greatest growth rate, accounting for more than one-half of total employment growth in the sciences. By 1986, they made up 40 percent of all scientists in industry. Mathematical scientists, many of whom work in computer-related areas, were the second most rapidly increasing group. Within engineering, employment of civil engineers showed the most rapid growth.

EXPENDITURES FOR RESEARCH AND DEVELOPMENT IN INDUSTRY

Trends in constant-dollar funds spent on industrial R&D are indicators of the level of R&D activity in industry. Funds for industrial R&D come almost exclusively from two sources: private industry itself and the Federal Government.³ Total estimated current-dollar expenditures for industrial R&D have increased markedly in the last several years, with \$85.7 billion estimated for

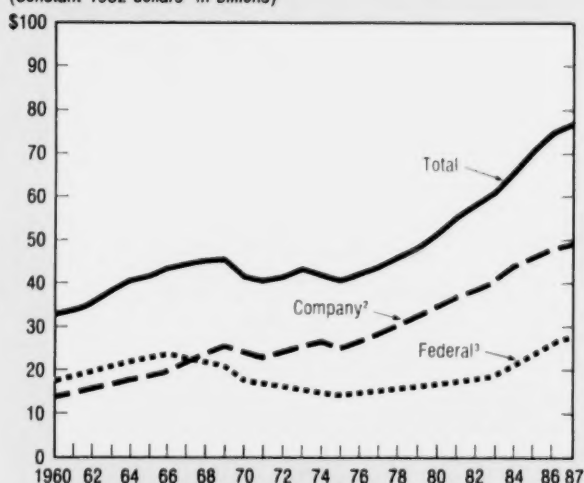
1986 and \$90.7 billion for 1987. (See figure O-28 in Overview.) This increase represents a 10.7-percent per year growth rate from 1980 to 1987 in current dollars. In constant-dollar terms, total R&D funding in industry has risen every year from 1975 to 1987 at an average rate of 5.4 percent per year; between 1980 and 1987, it has grown 5.8 percent per year. The 1986-87 increase, however, is estimated at only 2.5 percent. (See figure 6-2.)

Total R&D funding in the United States is estimated at \$124.3 billion in 1987; by this measure, industry performs 73 percent of the Nation's R&D. About 76 percent of funding for industrial R&D is for development, while development is only 36 percent of R&D expenditures in all other sectors combined.

Figure 6-2.

Expenditures for industrial R&D, by source of funds

(Constant 1982 dollars¹ in billions)



¹GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

²Includes all sources other than the Federal Government.

³Includes Federally Funded Research and Development Centers administered by industry.

Note: Preliminary data are shown for 1985 and estimates for 1986 and 1987.

See appendix table 6-2.

Science & Engineering Indicators — 1987

Trends in Company Funding

Both Federal and State Governments have been active in encouraging technology investments by private companies.⁴ For example, the Federal Government has taken measures to stimulate the economy, grant special tax credits for R&D, and clarify the restrictions on R&D consortia involving competing companies. Testifying to the success of such efforts, company funding in 1987 was

²See National Science Foundation (1985).

³The small amount of funding from other sources, such as State Governments, is combined with private company funding in the following discussion. Some companies perform "independent research and development" (IR&D), i.e., in-house R&D intended to better prepare the companies to bid on National Aeronautics and Space Administration or Department of Defense projects. Some of these expenditures are later reimbursed by the agency as overhead charges allocated to contracts. In this chapter, IR&D expenditures are counted as company-funded R&D.

⁴See U.S. Congress, Office of Technology Assessment (1984) and National Governors' Association (1983). Trends in collective industrial research in the United States and some other countries are studied in Haklisch, Fufeld, and Levenson (1984).

estimated to be 64 percent of all R&D expenditures in industry. (See figure 6-2.) The share of total industrial R&D outlays provided by industry first exceeded funding provided by the Government in 1968; it has continued to increase throughout the 1970's. In constant-dollar terms, the annual rate of increase in company R&D spending was 5.9 percent per year from 1975 to 1985. Preliminary data suggest, however, that the average annual rate of increase from 1985 to 1986 will be only 3.2 percent, and only 2.0 percent from 1986 to 1987. This slowing in the rate of increase is attributed to poor sales expectations, concerns for short-term profitability, and the restructuring of R&D efforts after corporate mergers.⁵

A variety of factors contributed to the recent high rate of private investment in R&D. In 1984, officials from about one-third of a group of large R&D-performing companies reported that the Economic Recovery Tax Act, which included a 25-percent tax credit for incremental R&D expenditures, had favorably influenced their R&D budgets.⁶ Moreover, constant-dollar company R&D expenditures did not decrease during the recession in the early 1980's (as they did in the recessions of 1970-71 and 1975). Instead, there was actually an increase, spurred by companies' concern that foreign competition is steadily eroding the U.S. technological lead.⁷ A recent study indicates that R&D contributed significantly to industrial productivity in both the 1960's and 1970's, in spite of the overall slowdown in productivity growth and the general worry about the possible exhaustion of technological opportunities. Basic research appeared to make an especially large contribution. Although Federally financed R&D expenditures had a positive effect on productivity, private support contributed significantly more.⁸

Trends in Federal Funding

While constant-dollar company funding for R&D has shown an almost uninterrupted increase, Federal funding has shown greater variations. Its historic high was in 1966; after this, cutbacks in many programs (particularly those at NASA) led to a steady overall decline that lasted until 1975. However, Federal constant-dollar expenditures for industrial R&D have increased since 1975 at an estimated 5.6 percent per year through 1987. (Note, however, that the increase from 1986 to 1987 is estimated at only 3.2 percent.) The recent increased emphasis on defense-related R&D has brought the Federal contribution, in constant dollars, back to its 1960's levels. For example, in fiscal year 1987, the Department of Defense (DoD) is contributing an estimated 85 percent of all Federal funding obligations for industrial R&D; in 1980, it only provided 70 percent.

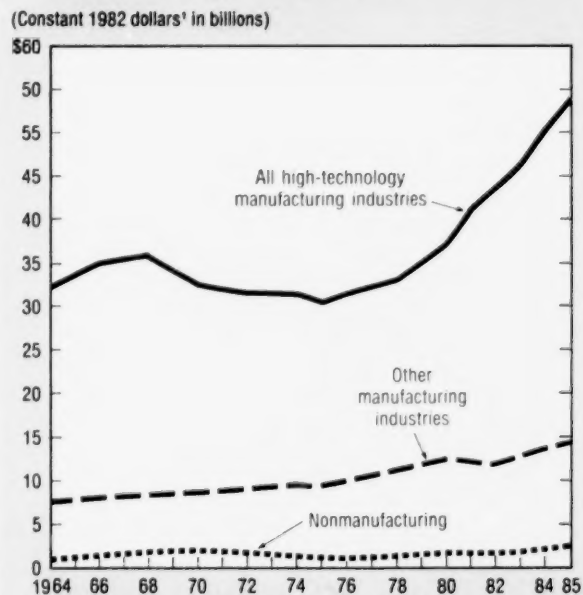
In addition to defense, the Government's policy is to increase support for civilian-oriented basic research, while giving considerably less emphasis to civilian applied research or development. From 1980 to 1987,

Federal obligations for industrial basic research—excluding DoD funding—increased by 119 percent, while applied research obligations increased only 13 percent and development obligations decreased by 26 percent. In terms of dollar amounts obligated, development remains by far the largest R&D component: in fiscal year 1987, an estimated 72 percent of all Federal funding obligations for industrial R&D will be for development.

R&D Expenditures and Employment in Individual Industries

Trends in R&D expenditures vary substantially among industries. For purposes of comparison, industries may be divided into three general groups: high-technology manufacturing, other manufacturing, and nonmanufacturing.⁹ (See figures O-29 in Overview and 6-3.) This division is in accordance with current policy interest in high technology, and also reflects the distinction between manufactured goods and services.

Figure 6-3.
R&D expenditures, by industry group



¹GNP implicit price deflator used to convert current dollars to constant 1982 dollars.

Note: Data include Federally Funded Research and Development Centers administered by industry.

See appendix table 6-3.

Science & Engineering Indicators — 1987

High-technology manufacturing industries accounted for 76 percent of total R&D funding in 1985. Other manufacturing industries accounted for 20 percent, while

⁵National Science Foundation (1987).

⁶See National Science Foundation (1984).

⁷*Business Week* (1984). This article contains a listing of the companies with the greatest R&D expenditures.

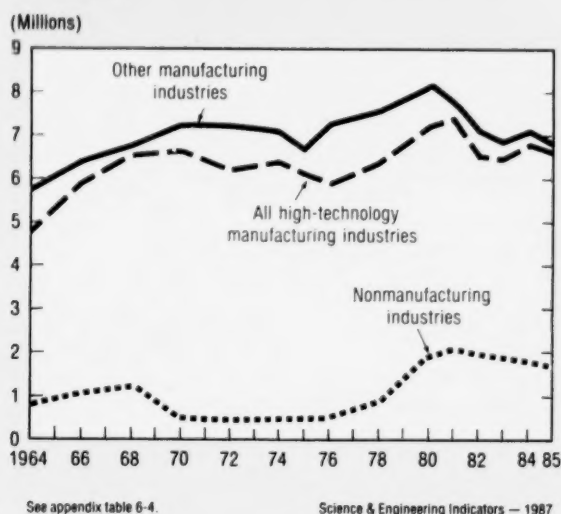
⁸See Griliches (1986).

⁹A list of the industries in each group is shown in appendix table 6-3. High-technology industries are identified in terms of the ratio of their R&D expenditures to their net sales.

nonmanufacturing (including services) accounted for only 4 percent. By comparison, in 1985 only 44 percent of total employment in R&D-performing companies was in high-technology manufacturing, while 45 percent was in other manufacturing, and 12 percent in nonmanufacturing.¹⁰ (See figure 6-4.)

During the 10-year period from 1975 to 1985, the average growth rates of R&D expenditures in the three sectors were 5.9 percent per year in high technology, 4.2 percent in other manufacturing, and 7.5 percent in nonmanufacturing, in constant-dollar terms.¹¹ During this interval, the growth rate in total employment was 1.1 percent per year in high-technology manufacturing, negative in other manufacturing, but large in R&D-performing nonmanufacturing (7.1 percent per year). This clearly reflects the shift in U.S. industry from goods to services.¹²

Figure 6-4.
Total employment of R&D-performing companies,
by Industry



Between 1980 and 1985—partly a period of economic slowdown—a somewhat different pattern emerged. R&D outlays in high-technology manufacturing increased considerably, rising at a rate of 7.6 percent per year in constant dollars. This was far above the increase in other manufacturing (2.4 percent per year) and the 3.9-

percent per year rise in nonmanufacturing. Employment in 1980-85 declined in both high-technology and other manufacturing industries (at rates of 1.4 percent and 3.2 percent per year, respectively) and in nonmanufacturing (1.3 percent per year).

The rapid increase from 1980 to 1985 in high-technology manufacturing R&D was partly due to the aircraft and missiles industry: Federal R&D expenditures in this industry grew at about 56 percent in constant dollars. In dollar terms, Federal support accounted for most of this industry's R&D growth.¹³ Another large increase during this period—51 percent, in constant dollars—was in private R&D expenditures in the chemical industry. (See appendix tables 6-5 and 6-6.)

Since 1980, large percentage increases in Federal support have occurred in nonelectric machinery, including computers (83 percent); and in communication equipment (68 percent), which is part of the electric equipment industry. Overall, the R&D support received by different industries from the Federal Government varies widely, ranging from 4 percent for the chemical industry to 76 percent for the aircraft and missiles industry. (See appendix table 6-7.)

PATENTED INVENTIONS

Industrial R&D produces many benefits for the performing company, among them a stream of new technical inventions that may in turn be embodied in innovations, i.e., in new or improved products, processes, and services. While there is no accepted method for directly counting such inventions, the patents taken out on new inventions can serve as indicators of invention.

Patenting indicators, while instructive and convenient, involve some well-known drawbacks. For instance, many inventions are not patented, yet patented inventions are implicitly taken to represent all inventions with respect to their distributions and rates of increase/decrease. In fact, industries vary considerably in their propensity to patent inventions rather than hold them as trade secrets. For this reason, comparison of patenting rates among different technologies or different industries is inadvisable. Further, counts of patents treat all counted patents as equal, although it is known that patents vary markedly in their technical and economic values. In the absence of an agreed-upon method for rating patents, however, the assumption of their equality is unavoidable. The problem of patent quality is further discussed later in this section.

Inventors and Owners of Inventions Patented in the United States

The U.S. Patent and Trademark Office issues patents to both U.S. and foreign inventors. The peak year for patents awarded to Americans and for total patents awarded was 1971. (See figure 6-5.) The recent low point was in 1983, but the rise from then to 1986 was a substantial 16

¹⁰Note that the nonmanufacturing employment figures discussed here do not apply to all nonmanufacturing industries, but only to those nonmanufacturing industries that report R&D expenditures.

¹¹As noted above, slower increases in total industrial R&D funding are estimated for 1987.

¹²More than one-half of the R&D expenditures and employment in this nonmanufacturing sector are in electric, gas, and sanitary services; computer and data processing services; miscellaneous business services (which include computer programming and other software, and R&D laboratories and commercial testing laboratories); and engineering, architectural, and surveying services. The peak year for total employment in R&D-performing nonmanufacturing was 1981.

¹³In 1985, the Federal Government paid for 76 percent of the R&D expenditures in this industry. Aircraft and missiles companies received 51 percent of all Federal R&D support to industry, and accounted for 8 percent of all private support.

percent for U.S. domestic patenting. Foreign patenting in the United States has generally increased between 1970 and 1986, with a 36-percent increase from 1983 to 1986.

These trends are open to various interpretations. If it is assumed that a country's domestic patenting is an indicator of its production of inventions,¹⁴ then the production of inventions in the United States declined in the 1970's. Similar declines were observed in many other industrialized countries, although there were steady increases in Japan. On the other hand, patenting by foreign countries in a large country like the United States may be taken as an indicator of the foreign levels of invention.¹⁵ Under this assumption, the increase of foreign patents in the United States would represent a genuine growth in foreign inventions. Further, the trend in the number of patents may not be the same as the trend in the value of those patents. For instance, preliminary studies of patenting in West Germany, the United Kingdom, and France show that the economic value of patents applied for in those countries did not drop in the early 1970's, even though the total number of patent applications was declining.¹⁶

¹⁴This approach is taken by Schiffel and Kitti (1978). The authors conclude that increasing world trade and the possibilities of exporting to a large and rich market seem to explain the increased foreign filings of patent applications in the United States. The conclusions and method of this study are critiqued by Bosworth (1980) and Basberg (1983).

¹⁵This approach, along with the preceding one, is discussed by Pavitt (1985).

¹⁶See Griliches, Pakes, and Hall (1986). These researchers found the distribution of patent values to be very broad and highly skewed. They do not therefore encourage use of patent counts to represent short-run changes in R&D output. They also found that the total value of patent rights is quite high, but still amounts to only 10 or 15 percent of a nation's total expenditure on R&D. Hence, there must be other significant means by which R&D performers seek returns from their investment.

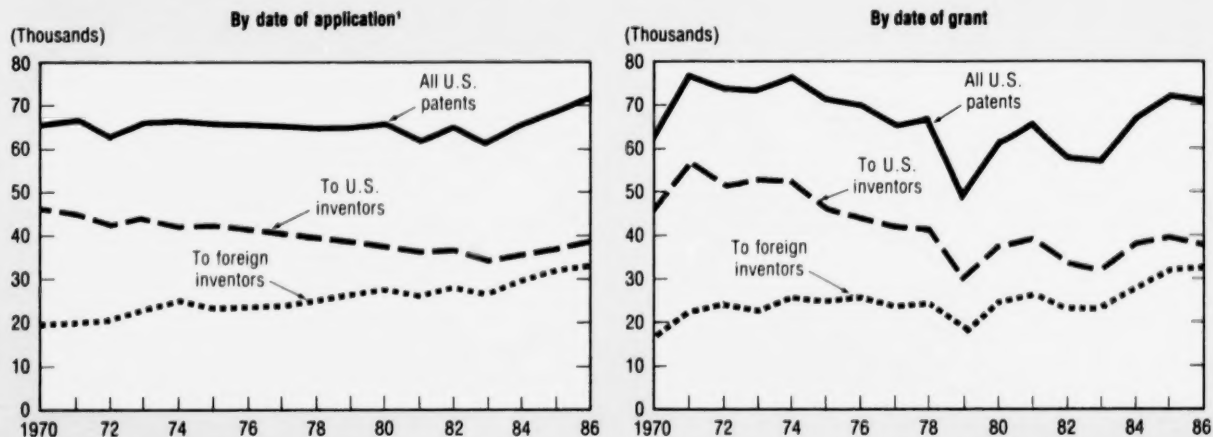
The data in terms of date of patent grant are quite irregular from year to year because of fluctuations in the rate of patent application processing by the Patent Office. To remove these fluctuations, granted patents can be counted in terms of the year in which each patent was applied for. (See figure 6-5.) The application date is roughly 2 or 3 years before the year of grant; it is therefore closer to the time in which the invention actually took place.

In terms of application date,¹⁷ foreign patenting again shows a pattern of fairly steady increase with a few dips in 1975 and the early 1980's. From 1983 to 1986, the increase in foreign patents has been about 8 percent per year. Patenting by Americans shows a much more complicated trend, with a peak in 1969 and a steady decline from 1975 to 1983. From 1983 to 1986, there was a slight recovery at a rate of about 4 percent per year.

The patents received by American inventors can be further analyzed according to their class of owner. (See figure 6-6.) Inventors who work for private companies or for the Government commonly assign ownership of their patents to their employer; self-employed inventors usually retain ownership of their patents. Thus, the owner's sector is a good indication of the sector in which the inventive work was done. In recent years, about 73 percent of U.S. patents have been assigned to corporations. Trends in corporate-owned patents have been very similar to the overall trends in U.S. patenting discussed

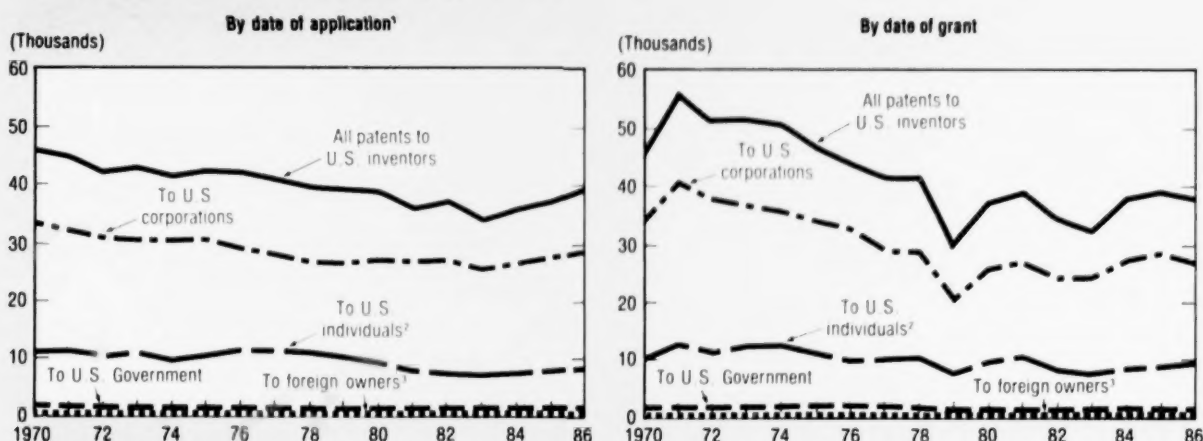
¹⁷Since many of the patent applications filed in recent years have not yet been examined by the Patent Office, it is not known how many of these will ultimately become granted patents. An estimate of the expected number of granted patents can be obtained by multiplying the total number of applications for each year by the recent success rate. These estimates are used for patenting rates by date of application throughout this chapter.

Figure 6-5.
U.S. patents granted, by nationality of inventor



¹Estimates are shown for 1982-86 for patenting by date of application.
See appendix table 6-8.

Figure 6-6.
U.S. patents granted to U.S. inventors, by type of owner



¹Estimates are shown for 1982-86 for patenting by date of application

²Includes unassigned patents

³Includes foreign corporations, governments, and individuals.

See appendix table 6-9.

Science & Engineering Indicators — 1987

above. In all three sectors, the patenting rate was at its most recent peak in the mid-1970's, and has been relatively flat since 1980.

Data on patenting by corporations include information on several kinds of small entities—i.e., universities, individuals, and small companies—whose patenting patterns are of interest in their own right. For example, about 1.4 percent of patents granted to Americans are currently assigned to universities. (See chapter 5, "Academic R&D and Basic Research: Patterns of Performance," for a discussion of the technical fields in which this patenting is concentrated.) Such patenting is encouraged by the Uniform Federal Patent Policy Act of 1980 (amended 1984), which permits nonprofit organizations and small businesses to retain patent rights for inventions achieved with Federal grant money. In 1986, 636 patents were granted to U.S. universities and colleges. While this represents an increase over earlier years (in 1976, U.S. universities were assigned only 345 patents), it does not reflect all of the inventive activity that takes place at universities. Although university staff and faculty may assign their patent rights to their institution, they also may sometimes retain the rights as individuals or assign them to small companies with which they are associated.¹⁸ Thus, a fuller picture of academic patenting trends is obtained by considering patenting by individuals and small companies. (See table 6-1.) Individuals, some of whom have a university affiliation, own about 20 percent of all U.S. patents. In addition, small business

entities have substantial rates of patenting; about 12 percent of patents awarded in 1986 were owned by small companies.¹⁹ Some of this patenting should also be credited to academic researchers.

The patents granted to foreign inventors can be assessed by country. (See figure 6-7 which shows the four largest foreign patenting countries.) Since 1975, Japan has been the largest foreign patenting country in terms of date of grant. Japanese inventors received 19 percent of all patents granted by the U.S. Patent and Trademark Office in 1986. The next largest foreign patenting nation

¹⁸These small business patents are identifiable because small entities are permitted to file for a partial rebate of the patent application fee. However, some of the patents for which the lower fee was paid were assigned to individual owners or were unassigned. If one counts only corporate owners, 10.0 percent of the patents granted in 1985, and 9.5 percent of those granted in 1986, were owned by small companies.

Table 6-1. Percent of U.S. patents granted to U.S. small entities

Year	Small business	Individuals	Colleges and universities
	Percent		
1983	NA	23.0	1.3
1984	NA	23.2	1.4
1985	12.6	23.4	1.4
1986	11.7	24.8	1.7

SOURCES: U.S. Patent and Trademark Office, *TAF Report: All Technologies Report* (April, 1986), *TAF Report: All Universities* (June, 1987), and unpublished data

Science & Engineering Indicators—1987

¹⁸Staff or faculty members may also license their patents to small or large companies, but licensing transactions are not reflected in the present data.

was West Germany, with 10 percent. Since 1980, Japanese patenting in the United States has increased 85 percent; the increases for West Germany (18 percent), the UK (0 percent), and France (13 percent) were much less.

In terms of patent applications, the results are similar. Japanese inventors in 1986 submitted 19 percent of all applications received by the U.S. Patent Office. American inventors submitted 53 percent. Since 1980, Japanese patent applications have increased by 77 percent, while West German applications have increased by 10 percent, British applications by 11 percent, and French applications by 17 percent. In contrast, American applications to the U.S. Patent Office increased by 5 percent from 1980 to 1986.²⁰

Patenting by Individual Countries in Various Technical Fields

The decline in patenting by Americans from the mid-1970's to 1983 occurred in many important technical areas,²¹ and may presage a shift in the economic condition of the corresponding industries. From 1975 to 1986, the share of U.S. patents granted to Americans dropped from 65 percent to 54 percent. (See appendix table 6-10.) Nearly all of this drop is due to the increase of Japanese-

origin patents. The U.S. share dropped most in the following areas: aircraft and parts;²² motor vehicles and other transportation equipment; and office, computing, and accounting machines (including computers). These are all fields in which Japanese patenting increased markedly. West German inventors increased their share of patenting in nonelectrical machinery. In general, the other countries have low shares of the patents in all fields; these shares did not change substantially.

The technology areas discussed above are very broad, and do not include some specific technologies of current interest. To study such technologies, patents were combined into special technology fields.²³ Unfortunately, this was not practical for some important fields, like biotechnology, but 15 fields of interest were developed. (See appendix table 6-11.)

U.S. patenting, in terms of counts of patents, increased from 1975 to 1986 in 6 of the 15 fields and decreased in the others. The share of patents going to Americans decreased in every field except genetic engineering. Although this is a narrowly defined field and contains few patents, the U.S. share here rose considerably, increasing from 27 to 78 percent. On the other hand, the U.S. share of patents in internal combustion engines dropped from 54 to 28 percent.

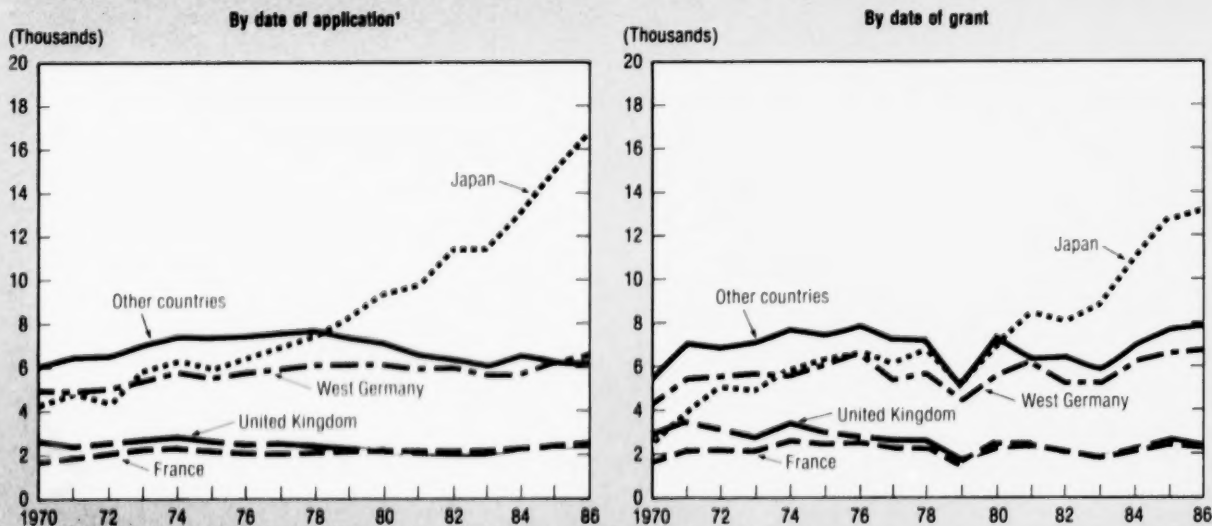
²⁰Data from the U.S. Patent and Trademark Office, special tabulations.

²¹Patenting in these technical areas was estimated by means of the "Concordance," a computer program maintained by the U.S. Patent and Trademark Office that converts patent counts from the Patent Office classification system into patent counts in terms of Standard Industrial Classification (SIC).

²²The large Japanese increase in this field, along with motor vehicles and other transportation, suggests the possibility that some automotive patents are illegitimately being counted as aircraft patents. See U.S. Patent and Trademark Office (1985), pp. 80-81.

²³In this case, the Concordance was not used, but Patent Office subclasses were directly combined to make up the technologies of interest.

Figure 6-7
U.S. patents granted to foreign inventors, by nationality of inventor



¹Estimates are shown for 1982-86 for patenting by date of application. See appendix table 6-8.

Science & Engineering Indicators — 1987

The Japanese share of patents increased in every technology except genetic engineering, and especially in internal combustion engines (from 17 percent to 44 percent) and in laser light sources and detectors (from 14 percent to 35 percent). Increased West German participation is seen in light-wave technology and in robots, although the total number of patents involved is small; increased French activity is found in nuclear energy.

Citations from Patents to Previous Patents

One of the main problems in using patent counts as indicators of the volume of technical invention is that not all patents are equally significant. Of the several promising approaches to this problem that have been suggested, one involves the use of interpatent citations.

The front page of a patent document generally contains a list of previous patents that serve as "prior art," i.e., previous significant achievements in the same field of invention that must be taken into account in judging the novelty and significance of the present invention. Such lists of citations therefore indicate which are the most significant patents in a given field: patents receiving many citations from later patents are presumably more technically important than those receiving few citations.²¹

U.S. patent citation data suggest that Japanese patents are not only increasingly numerous in the U.S., but that they are also of especially high quality. (See table 6-2.) The patents taken out by American inventors in 1975 had received an average of 3.05 citations each by the end of 1986. This was surpassed only by the Japanese patents, which received 3.30 citations on average in the same period. All other countries shown received a lower number of citations. These numbers reflect citations from

U.S. Patent and Trademark Office examiners who evaluate patent applications in terms of their significance and novelty. These patent examiners accorded somewhat more importance to patents granted to Japanese applicants in 1975 than to those granted to Americans. If one assumes that American patent examiners would tend to prefer citing American patents, then their emphasis on Japanese patents becomes all the more striking.

Patents owned by U.S. corporations and by foreign entities were more often cited by American applicants than were patents owned by the U.S. Government or by individual Americans. Overall, the patents granted to Japanese inventors in 1975 were cited about as often as those granted to U.S. corporations—about 3.3 times each—on average. Since it is likely that the Japanese patents are mostly corporate-owned, it appears that those U.S. and Japanese corporate-owned patents taken out in the U.S. are of about the same quality. This argument does not explain, however, why the patents from nationals of other countries are less frequently cited.

It would be helpful to have the rates of citation to more recent patents. Unfortunately, since it takes many years for a patent to receive all its citations, patents granted in recent years have only a small fraction of the citations they will eventually have. For patents granted in 1983, the data on these incomplete citations show that the relative quality of Japanese patents was even higher than in 1975. (See table 6-2.) Patents with U.S. inventors are again more frequently cited than those coming from the other eight countries, but patents with Japanese inventors are cited even more than patents with U.S. inventors owned by U.S. corporations.

The success rate of applications to the U.S. Patent Office provides supplementary information on the quality of patents from different countries. (See appendix table 6-12.) Because of the importance of the United States as a market, significant inventions in various countries are commonly patented here as well as in their home country if there is any chance that they can be exploited in the U.S. through trade or licensing. Of the patent applica-

Table 6-2. Citations from U.S. patents to earlier U.S. patents, by country of inventor or sector of owner of cited patents

Year of cited patents	Country of inventor									
	United States	Japan	Netherlands	United Kingdom	West Germany	Canada	Sweden	France	Switzerland	Italy
Citations per citable patent										
1975	3.05	3.30	2.93	2.87	2.65	2.57	2.46	2.43	2.42	2.41
1983 ¹	0.68	0.92	0.62	0.59	0.59	0.53	0.51	0.58	0.57	0.49
Sector of owner, for U.S. inventors										
Citations per citable patent										
All U.S. inventors										
U.S. corporations										
U.S. government										
U.S. individuals										
Foreign owners										
1975	3.05		3.27		2.28		2.53		3.32	
1983 ¹	0.68		0.75		0.48		0.47		0.80	

¹ These numbers are expected to increase as more citations are made to 1983 patents in later years.

SOURCE: Computer Horizons, Inc., unpublished tabulations provided to the National Science Foundation

Science & Engineering Indicators—1987

tions filed in the U.S. by nationals of different countries in 1975 and 1981,²⁵ Japanese applicants have been particularly successful (French applicants in 1975 also had a high success rate). These data, of course, are subject to various interpretations. For example, the low success rate for British and Canadian applicants may be due to the common use of English, which makes it easier for them to file applications in the U.S., and thereby may lower the average quality of the filings. Conceivably, Japanese filings are of especially high quality for a similar reason, but in any case the data do not support the supposition that the large number of Japanese filings is associated with a lower average quality. Several foreign countries have higher success rates than do American applicants: this supports the idea that foreign countries file their most important inventions in the United States, rather than a uniform selection of their inventions of all qualities.²⁶

SMALL BUSINESS IN HIGH TECHNOLOGY

The role of small businesses within the science and technology system is ambiguous and controversial. On the one hand, they are believed to be disproportionately innovative; to be less tied to existing products and processes than are large, well-established firms; and/or to offer better incentives to their S/E workers, who are more likely to hold substantial ownership interests in their work. Small businesses may also be better able to exploit small market niches that are ignored by larger firms. On the other hand, they are seen as generally lacking the financial, production, and marketing resources of larger firms; they may also be unable to reduce their exposure to risk through diversification. Furthermore, if a small firm does succeed in identifying and developing a successful innovation, it typically must be able to expand its production and marketing efforts rapidly in order to profit from its innovation.

Regardless of whether small businesses are more or less innovative than larger firms, their ability to prosper is probably a major element in keeping the American economy competitive, and in maintaining its ability to develop, adopt, and diffuse new technologies. The creation and growth of small companies based on innovations—particularly those marketing new products—provide an alternative channel for introducing new technologies. While large enterprises, with their R&D programs and established technical and marketing expertise, will certainly continue to provide a major share of the Nation's inventions and innovations, there will be circumstances wherein the established firm will not be an effective vehicle for introducing new technologies. The small business alternative is therefore of great interest, although it is not always the superior vehicle for innovation.

No instruments exist for directly measuring the relative effectiveness of small business as an agent for technological change. This section therefore concentrates on measures of the viability of small firms, particularly in

high-technology industries. It covers indicators of small business activity in high-technology industry overall, as well as detailed information on the financial environment for small high-technology enterprise, and information about small business in biotechnology, an important high-technology area.

This discussion generally follows the Small Business Administration (SBA) rule of describing firms with less than 500 employees as small businesses, and those with 500 or more employees as medium or large.²⁷ Definition of high-technology firms is more difficult. For this analysis certain products or industries first are identified as high-technology, then firms producing such goods or belonging to such industries are classified as high-technology firms. The primary division of industries into high-technology and non-high-technology industries is the DOC-3 classification, based on direct and indirect R&D expenditures attributed to a product as a percent of net sales.²⁸

Employment in Small High-Technology Enterprises

Employment is a useful indicator of the level of activity within a sector of the economy. In 1984, small firms in high-technology manufacturing industries employed more than 710,000 people, up from about 590,000 in 1980. In three technology-related service industries (computer and data processing services; engineering, architectural, and surveying services; and noncommercial educational, scientific, and research organizations), another 682,000 were employed in small firms in 1984, compared to 542,000 in 1980. Small firms accounted for about one-quarter of employment in the high-technology manufacturing and technology-related service industries. (See table 6-3.) This is a substantially lower share of employment than is accounted for by small businesses in the U.S. economy as a whole. In 1984, small firms accounted for 56 percent of all manufacturing industry employment in the United States,²⁹ and about 80 percent of employment in the private sector as a whole. (See appendix table 6-13.)

These employment data may understate the role of small business in high-technology industry. First, it is not surprising that "small business" accounts for a much larger share of employment in the rest of the economy than in the high-technology sector. The service industries in particular are dominated by very small businesses (e.g., service stations, restaurants, haircutters, etc.). Second, the identification of high-technology industries is based on reported R&D expenditures. Small businesses

²⁵This (1981) is the last year for which a substantial share of applications have been processed, as of the end of 1986.

²⁶The patent citation data discussed above gave some support to this interpretation, but only in the case of Japan.

²⁷The definition of small businesses using a size cutoff, based either on employment or sales, clearly involves an arbitrary choice. The selection of a different cutoff would certainly alter the trends and levels reported here. In this discussion the data are available according to specified cutoffs, which are reasonable—if imperfect—indicators of small business status.

²⁸Indirect R&D expenditures are the share of R&D expenditures by industries supplying the industry which are attributed to the industry, using an input-output table. See U.S. Department of Commerce, International Trade Administration (1983), pp. 33-37. See also the discussion on p. 133 of chapter 7, "The International Markets for U.S. Technology."

²⁹See U.S. Department of Commerce, Bureau of the Census (1986), p. 507.

Table 6-3. Employment in high-technology industries, by size of firm and industry

Industries	Small firms		Large firms		Small firms' share of total employment		Distribution of employment by small high-technology firms	
	1980	1984	1980	1984	1980	1984	1980	1984
	Percent							
High-technology manufacturing industries ²	591,332	710,421	2,930,019	3,195,418	16.8	18.2	52.2	51.0
Guided missiles & spacecraft	991	1,485	88,839	100,388	1.1	1.5	0.1	0.1
Communications equipment & electronic components	265,358	317,882	965,324	1,108,090	21.6	22.3	23.4	22.8
Aircraft & parts	44,558	47,147	507,756	498,352	8.1	8.6	3.9	3.4
Office, computing & accounting machines	49,898	86,888	347,548	472,815	12.6	15.5	4.4	6.2
Drugs & medicines	31,154	35,228	196,762	181,299	13.7	16.3	2.7	2.5
Industrial inorganic chemicals ...	7,074	5,437	54,382	53,138	11.5	9.3	0.6	0.4
Professional & scientific instruments	160,134	184,079	380,934	440,763	29.6	29.5	14.1	13.2
Engines & turbines	6,066	6,813	172,659	158,304	3.4	4.1	0.5	0.5
Plastic materials & synthetics	26,099	25,462	215,815	182,269	10.8	12.3	2.3	1.8
Technology-related service industries ³	542,032	682,055	542,755	589,622	50.0	53.6	47.8	49.0
Computer & data processing services	150,019	242,643	156,037	241,646	49.0	50.1	13.2	17.4
Engineering, architectural & surveying services	357,529	403,944	264,174	288,799	57.5	58.3	31.5	29.0
Noncommercial educational, scientific, and research organizations	34,484	35,468	122,544	59,177	22.0	37.5	3.0	2.5
All technology-related industries ...	1,133,364	1,392,476	3,472,774	3,785,040	24.6	26.9	100.0	100.0

¹ Firms with less than 500 employees.

² Industries whose products meet the DOC-3 criteria for high-technology products. See U.S. Department of Commerce, International Trade Administration, *An Assessment of U.S. Competitiveness in High Technology Industries* (February, 1983), pp.33-37.

³ Service industries identified by the Small Business Administration as high technology, but excluding "Business Services, N.E.C." and "Service Industries, N.E.C."

SOURCE: U.S. Small Business Administration, Office of Advocacy, special tabulations.

Science & Engineering Indicators—1987

are less likely to have separately budgeted R&D expenditures, or distinct R&D departments, than are larger firms. The industries reporting high R&D expenditures may therefore be those dominated by large firms. Third, the successful small high-technology firm will generally grow larger—either through internal growth or through merger³¹ with other firms—in order to exploit its innovations.

One measure of the success of high-technology enterprise might be the growth of employment in those industries relative to the rest of the economy.³² Employment in the technology-related industries was 12 percent higher in 1984 than in 1980, while total private sector employment grew by about 4 percent. (See table 6-3 and appen-

dix table 6-13.) Employment in small firms in the technology-related industries grew by about 20 percent during this period, while employment in all small businesses grew by 6 percent.

The vitality of the small high-technology business sector is even more striking when it is considered that some of the firms counted as small, high-technology enterprises in 1980 had, by 1984, become large firms. Thus, 581 firms—which in 1980 accounted for almost 10 percent of employment in small business high-technology manufacturing establishments—were no longer counted as small businesses in 1984, either because of internal growth or because merger and acquisition activity had made them parts of larger enterprises. (See table 6-4.)

The tendency for small businesses to become large ones varies considerably among industries. For example, relatively few small firms in the technology-related service industries grow or merge into large firms. This is not surprising, as large firms are relatively unimportant in these industries, accounting for about 46 percent of their employment in 1984, as compared—on the other hand—

³¹ "Merger" is defined here to include all cases where the firm is joined with another firm, whether the transaction involves the purchase of one firm by another or exchanges of stock and other poolings of ownership.

³² It should be noted, however, that a successful process innovation may involve a simultaneous increase in sales and reduction in employment, if the associated increase in labor productivity is sufficient.

with 82 percent in high-technology manufacturing industries. (See table 6-3.) In some high-technology manufacturing industries, there is a fairly strong tendency for small businesses to gain large status: firms accounting for 16.0 percent of 1980 small business employment in the office, computing, and accounting machine industry were part of large firms in 1984; as were industrial inorganic chemicals firms (14.5 percent of 1980 employment); and firms in communications equipment and electronic components and in drugs and medicines (more than 10 percent of 1980 employment in each). (See table 6-4.)

Of these four industries, only in one—communications equipment and electronic components—was small business relatively important, accounting for about 20 percent of employment in both 1980 and 1984. In the other industries with fairly strong tendencies for small firms to grow larger, small business accounted for less than 15 percent of industry employment in 1980. It is entirely possible, therefore, that the shift of these firms from small status to large was in response to factors that make a large-size firm optimal for those industries, rather than being a demonstration of small businesses' flexibility and technological dynamism. On the other hand,

Table 6-4. Employment of small business,¹ high-technology establishments that in 1984 were non-small-business, high-technology establishments, by industry: 1980, 1984

Industries	1980 Small business (SB), high-technology (HT) establishments		1984 non-small-business, high-technology establishments which were small-business, high-technology in 1980					
	Number	Employment	1980		1984 ²		1980 share of all 1980 SB, HT establishments	
			Number	Employment	Number	Employment	Number	Employment
							Percent	
High-technology manufacturing industries ³	23,774	591,332	581	52,797	581	88,548	2.4	8.9
Guided missiles & spacecraft	28	991	1	30	1	50	3.6	3.0
Communications equipment & electronic components ..	9,934	265,358	261	27,508	261	45,491	2.6	10.4
Aircraft & parts	1,282	44,558	21	2,064	21	2,592	1.6	4.6
Office, computing & accounting machines	1,667	49,898	101	7,986	101	16,340	6.1	16.0
Drugs & medicines	1,359	31,154	38	3,716	38	5,025	2.8	11.9
Industrial inorganic chemicals	332	7,074	24	1,027	24	1,102	7.2	14.5
Professional & scientific instruments	7,880	160,134	101	9,281	101	13,924	1.3	5.8
Engines & turbines	290	6,066	2	54	2	39	0.7	0.9
Plastic materials & synthetics	1,002	26,099	32	1,131	32	3,985	3.2	4.3
Technology-related service industries ⁴	45,426	542,032	533	27,846	533	40,866	1.2	5.1
Computer & data processing services	12,268	150,019	294	13,059	294	21,442	2.4	8.7
Engineering, architectural & surveying services	31,526	357,529	227	14,200	227	18,690	0.7	4.0
Noncommercial educational, scientific, and research organizations	1,632	34,484	12	587	12	734	0.7	1.7
All technology-related industries	69,200	1,133,364	1,114	80,643	1,114	129,414	1.6	7.1

¹ Firms with less than 500 employees.

² Broken down by 1980 industry

³ Industries whose products meet the DOC-3 criteria for high-technology products. See U.S. Department of Commerce, International Trade Administration, *An Assessment of U.S. Competitiveness in High Technology Industries* (February, 1983), pp.33-37.

⁴ Service industries classified by the Small Business Administration as high technology, but excluding "Business Services, N.E.C." and "Service Industries, N.E.C."

SOURCE: U.S. Small Business Administration, Office of Advocacy, special tabulations

Science & Engineering Indicators—1987

the share of employment accounted for by small firms increased between 1980 and 1984 from 12.6 percent to 15.5 percent in the office, computing, and accounting machine industry; and from 13.7 to 16.3 percent in the drugs and medicines industry. In these industries, small businesses seem to be increasingly viable. Furthermore, since relatively large numbers of small firms in these industries grow to medium- or large-firm status, the growth of such small firms seems to follow technological or other commercial success.

Venture Capital and High-Technology Enterprise

The growth of small businesses and the introduction of new products require access to pools of capital. Compared to larger firms, small businesses—particularly new firms that seek to develop and exploit a new technology—are handicapped by both the lack of a financial track record and a narrow scope of business activities. These factors combine to make it difficult for a firm to secure traditional financial support, i.e., obtaining bank loans or selling equity in the stock markets. In the United States, the need for financing for small, innovative firms has been at least partially met by a variety of funding mechanisms not generally available outside the U.S. These include an active venture capital industry (described below), small-firm equity markets—such as the NASDAQ listings and markets made by individual stock brokerages—and other financing systems, such as personal funds, funds from wealthy families and individuals, and trust funds.

Venture capitalists invest in small, young, rapidly growing companies that may not have access to public or credit-oriented institutional funding. Their investments may be divided into three classes, two of which are of primary concern here.³² First, early-stage investments support the entrepreneur or inventor up through initial commercial manufacturing and sales. Later-stage financing supports firms that are producing and shipping, but are as yet unable to finance substantial expansions and investments in plant. Later-stage financing is typically geared toward the sale of stock to the public, known as the Initial Public Offering (IPO). Most venture capital investments are equity-related, either through direct purchase of stock or through options and other equity-related arrangements. These investments usually emphasize long-term (5 to 10 years) opportunities, and closely involve the investors with the operations of the capital recipient, frequently through participation on the board of directors.

In 1985, the pool of capital managed by venture capital firms was \$24.1 billion, 6.9 times as great as it was in 1978. (See appendix table 6-14.) During this period when venture capital emerged as a strong source of finance for small, innovative firms, new funds made available to venture capitalists grew from \$600 million in 1978 to \$4.5 billion in 1986. The venture capitalists in turn increased their investments (excluding debt lending and financing

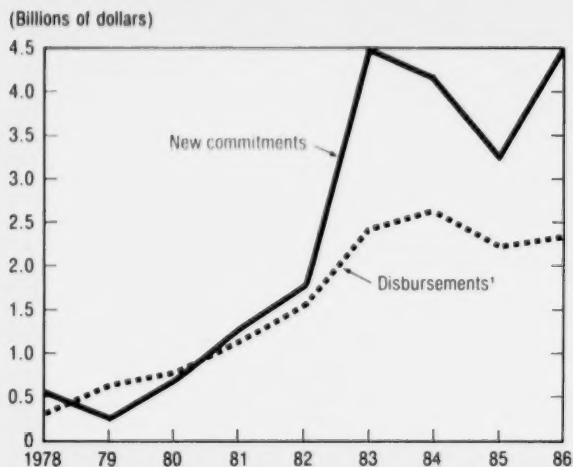
for leveraged buyouts) from about \$300 million in 1978 to some \$2.7 billion in 1984, and to \$2.4 billion in 1986. (See figure 6-8.)

During the last 3 years studied, new capital commitments have exceeded disbursements by the venture capital industry, even when debt financing and leveraged buyout financing are taken into account. There is thus apparently a surplus of venture funds seeking outlets in new or expanding innovative firms. This surplus could dry up as quickly as it appeared: the venture capital industry is highly sensitive to the business cycle and to changes in tax laws, particularly with respect to the treatment of long-term capital gains.

In 1986, early- and later-stage investments combined accounted for about 93 percent of all venture capital disbursements. (See appendix tables 6-14 and 6-15.) The industry producing computers and computer-related products and services received the largest share of both early- and later-stage investments: this industry received \$254 million in early-stage financing and \$429 million in later-stage financing in 1986. Other industries receiving substantial venture capital investments were the communications industries, and those producing electronic components and other electronic products (including instruments).

Biotechnology (including recombinant DNA, monoclonal antibodies and hybridomas, and other genetic engineering) has received smaller, but increasing, amounts of venture capital during the years for which data are available. In 1984, this industry received about \$63 million in early- and later-stage investments; in 1986, it received \$117 million. Interestingly, biotechnology venture capital was more concentrated in later-stage investment than for any other industry except industrial equip-

Figure 6-8.
Venture capital commitments and disbursements



³²Excluding SBIC straight debt lending and leveraged buyout financing.
See appendix table 6-14.

Science & Engineering Indicators — 1987

³²Definitions and discussion are based on Venture Economics, Inc. (1985).

ment, which was an insignificant recipient of venture capital. Either the biotechnology industry is experiencing a lower rate of new-firm introduction than are some of the other—presumably better established—industries (e.g., computers, communications, and electronic components), or there are other sources of funds for new entrants that are at present more important than venture capital, e.g., investments by large pharmaceutical concerns. (See appendix table 6-15.)

Initial Public Offerings are another indicator of the financial development of new firms. At this stage, a firm is presumably well enough established—either through access to superior technology or through actual production and sales capability—that it can raise money through the stock market. The computer and computer-related industry received the bulk of investment reported, although its share was falling: about 54 percent of all venture-backed IPO's by small businesses in 1984, and 26 percent of such IPO's in 1986. IPO's were more heavily oriented toward non-high-technology industries (particularly consumer goods, but also industrial equipment and machinery) than were direct venture capital investments, presumably reflecting the greater certainty associated with new firms in industries with well-established technologies and product lines. In 1986, there was a surge of venture-backed IPO's in biotechnology firms, with almost \$270 million (or 18 percent of the total capital) raised in this fashion. (See appendix table 6-16.)

Small Business and Biotechnology

The biotechnology industry is particularly important to a study of business—especially small business—in the science and technology system. First, it is an industry that has a large science component, using techniques such as recombinant DNA and hybridomas that are the continuing subject of intensive work in university and private basic research laboratories. Second, the biotechnology industry is one whose leaders have emerged from the ranks of small business. Genentech, for example, was formed in 1976, made its IPO in 1980, and by 1984 still employed only 560; Cetus was formed in 1971, made its IPO in 1981, and employed 600 in 1985.³³

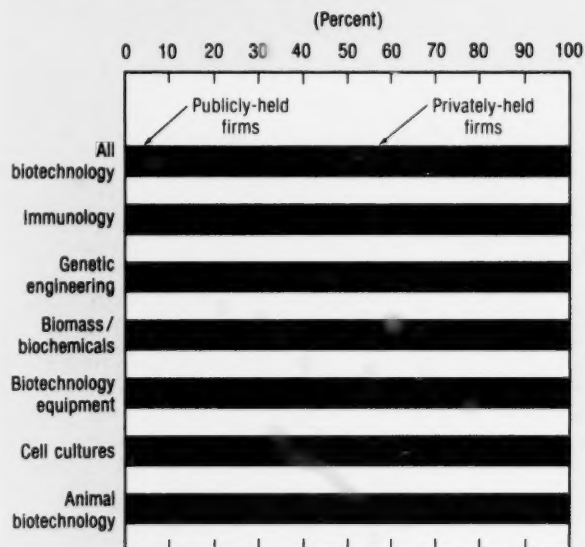
To examine more closely small business' role in the biotechnology industry, a commercial data base containing a large number of firms active in high-technology industries was searched. The data base attempts to be all-inclusive; when prospective firms are identified, questionnaires are sent covering their size, status (private or public, independent, subsidiary, or joint venture), year formed, and product groups in which they are active. The version of the data base used here includes more than 12,000 firms. Of these, 380 reported activity—i.e., either production, sales, or R&D activity—in the fields defined by the data base as biotechnology.³⁴

There were 252 independent firms with fewer than 1,000 employees active in biotechnology in the data base. There were also 7 independent firms with more than 1,000 employees, and 120 firms that were either joint ventures or subsidiaries of larger firms, of which 95 reported fewer than 1,000 employees. Although some of the latter firms probably can also be characterized as small businesses, it is not practical to separate them from the small subsidiaries of medium and large businesses. Discussion here therefore concentrates on the 252 small independent firms.

More than one-half of these firms were active in either genetic engineering or biotechnology equipment. About one-sixth of the firms were active in cell cultures, while many were also active in animal biotechnology, immunology, and biomass/biochemicals. (See appendix table 6-17.) There was relatively little cross-technology activity, except between genetic engineering and immunology, where 11 firms—almost one-sixth of those firms reporting activity in genetic engineering, and more than one-third of the immunology firms—were active in both. Perhaps surprisingly, the firms active in biotechnology equipment were not highly involved in other technologies.

About one-quarter of the 252 firms were publicly held. There is, however, some variation in this: close to 40 percent of the firms active in immunology were public, as were about 30 percent of the firms in genetic engineering. (See figure 6-9.) These technologies are at the heart of the biotechnology revolution, encompassing the testing and

Figure 6-9.
Small' firms active in biotechnology,
by status of firms: 1986



³³Firms with fewer than 1,000 employees.

See appendix table 6-18.

Science & Engineering Indicators — 1987

³³See Dibner (1986), table 5.1.

³⁴The data base used is the CorpTech data base, provided by Corporate Technology Information Services, Inc., Wellesley Hills, MA. See appendix table 6-17 for a list of the biotechnology classes used.

diagnostics market and the recombinant DNA technique. The other technologies described here may be more specialized areas that one might expect to develop during later stages of the industry's growth.

The data base reports firm age, based on year of firm founding. The number of small biotechnology firms founded annually increased steadily through the late 1970's, reaching a peak of 40 firms in 1980. New firm formation remained at a high level during 1982 and 1983. It is not clear whether the smaller number of firms in the data base that were formed during 1984 and 1985 indicates a decrease in the actual formation of new biotechnology firms, or if it reflects the time for a firm to be included in the data base. Examining the age of firms in individual technologies, the rate of new firm formation in immunology fell sharply after 1981, when almost one-third of the firms active in immunology were formed. The number of new firms in genetic engineering has also decreased sharply since 1981 and 1982. In contrast, cell cultures and animal biotechnology seem to be the subject of more recent attention. A large number of firms active in biotechnology equipment were formed prior to the biotechnology revolution—29 of the 67 equipment firms were formed prior to 1975. This presumably reflects a migration of established instrumentation and fermentation firms into the new industry. There has also been, however, a substantial increase recently in the number of new firms active in the equipment industry; this perhaps reflects the development of new processes and equipment in the pursuit of new products. (See appendix table 6-19.)

Combining the information about the traded status of small firms with that about the firms' ages suggests that the biotechnology revolution has in fact reached a stage of consolidation, as new firms increasingly move into specialized niches (such as animal biotechnology, cell cultures, and equipment), leaving the core areas of immunology and genetic engineering to those firms who established early leading positions.

As the data base matures, it should be possible to follow in greater detail the evolution of this exciting industry, and to extend its use to other new areas. In the meantime, analysis of the biotechnology industry should be considered as preliminary.

TECHNOLOGICAL INNOVATION IN INDUSTRY

The indicators so far considered in this chapter have described the resources devoted to innovation (e.g., science and engineering employment), or intermediate products (e.g., patented inventions). None of these is a valid measure of the output of technological innovation produced by these efforts. Such a measure would be especially useful to have in view of the current policy interest in maintaining and improving U.S. industrial competitiveness through the creation and implementation of new technology. Innovation as such is unfortunately difficult to measure, but the results of some limited studies are presented in the following paragraphs.

Innovation and Innovative Efforts Across U.S. Industry

One survey of 620 manufacturing companies⁵⁵ permits an estimate of the output of new products first marketed in 1985.⁵⁶ (See figure O-30 in Overview.) In terms of company size, the smallest companies clearly produced the greatest number of new products per million dollars of R&D; this is also true of the number of products per million dollars of net sales. (See appendix table 6-20.) In addition, the number of products per R&D or sales dollar decreases uniformly as company size increases. This shows that small companies are especially dependent on the sale of new products.

R&D expenditures accounted for about 40 percent of the average costs associated with the products first introduced in 1985. The remaining costs were equally split among plant and equipment, production and startup, and marketing and advertising.⁵⁷ These proportions were about the same for companies of different sizes. The proportion of new product costs attributed to R&D ranged from 50 percent in the electrical equipment industry to 26 percent in the food industry.

The responding firms reported that new products first marketed in the 1981-85 period accounted, on average, for 25 percent of 1985 sales.⁵⁸ In terms of individual industries, instrument firms and electrical equipment firms reported, on average, that more than 40 percent of their 1985 sales were due to such new products, as compared with slightly more than 10 percent for printing companies and food companies. Companies with sales of \$200 million or less reported a greater proportion of sales attributable to new products (about 30 percent) than did larger companies (about 20 percent).

The responding firms were divided into three groups according to their size and industry. A group of large R&D-intensive companies was identified, where each company had at least \$1 billion in gross annual sales in 1985 and belonged to an R&D-intensive industry.⁵⁹ A second group belonged to the same R&D-intensive industries, but had gross annual sales between \$35 million and \$1 billion. A third group included companies in both size ranges but in the remaining, non-R&D-intensive manufacturing industries.

An important strategy for developing new technology is the award of research grants or contracts to univer-

⁵⁵Hansen, et al. (1987).

⁵⁶A new product is defined as one—newly produced by the responding firm—whose features, performance, or cost is substantially different from its earlier products. Thus the product may in fact have been produced earlier by another company.

⁵⁷The choices offered were: (1) research and development; (2) purchase, installation, and renovation of plant and equipment; (3) production startup, including trial production runs; and (4) marketing, sales, and advertising for new product introduction.

⁵⁸Note that this is a different group of new products from that discussed in the preceding paragraph.

⁵⁹These industries were defined as those with an R&D/net sales ratio of at least 1 percent, in addition to those that annually spend at least \$1 billion on R&D.

sities.¹⁰ Nearly 80 percent of the large R&D-intensive companies made such awards during 1985, as opposed to about 30 percent of the smaller R&D-intensive firms and less than 25 percent of the non-R&D-intensive firms. The granting of such awards was directly related to company size, with 100 percent of firms with gross sales more than \$4 billion and less than 15 percent of those with sales below \$65 million making R&D grants or contracts.¹¹

Many of the responding firms participate in the venture capital industry by holding equity positions in separate firms providing capital to new technological ventures. Overall, 9 percent of firms reported doing this, including 26 percent of large R&D-intensive companies, 6 percent of smaller R&D-intensive firms, and 7 percent of non-R&D-intensive firms. Similarly, 18 percent of large R&D-intensive firms were involved in establishing R&D limited partnerships, either as limited or general partners. Only 8 percent of the smaller firms did this, and only 3 percent of the non-R&D-intensive firms. On average, a firm engaged in 1.5 such partnerships. Both venture capital investment and involvement in R&D partnerships are means by which companies intend to exploit new technological developments.

Technological Innovation in Individual Technologies

For a few technologies, results are available on the production of innovations over a period of time. Estimates thus can be made of the rates of innovative output

in these technologies and also of output quality. The data are based on a survey of innovations published in the relevant technical journals in the indicated years.¹² Two industries are shown, chemicals and textiles. They were selected because, although productivity growth declined in the 1970's in the chemical industry and increased in textiles,¹³ productivity trends for both industries seem to be largely due to the rate of production of innovations.¹⁴

Chemical technologies are divided into chemical products (new materials), chemical processes, process equipment, and process instruments. (See table 6-5.) These are considered the main types of technology of interest to the chemical industry.¹⁵ New materials and processes are most likely to come from the industry itself; equipment and instrumentation often come from supplier industries. There was almost a 90-percent drop in the number of product innovations from the first period to the second. (See table 6-5.) More relevant to productivity, there was a drop of 17 percent in process innovations, 47 percent in equipment innovations, and 39 percent in instruments, which parallels the observed productivity drop.

Incomplete results suggest that many of the process innovations in the second and third periods were pollution- and energy-related rather than productivity-en-

¹⁰For the method, see Bailey and Chakrabarti (1985), pp. 609-639.

¹¹Specifically, multi-factor productivity in the chemical industry (adjusted for changes in capacity utilization) dropped from 3.10 percent per year in 1965-73 to 1.91 percent per year in 1973-79, returning to 2.53 percent per year in 1980-82. In textiles, the corresponding numbers were 2.73, 3.56, and 3.38. See Bailey and Chakrabarti (1985), p. 615.

¹²See Bailey and Chakrabarti (1985), p. 630, for the data. Additional reasons are given for the productivity slowdown, including a decrease in the rate of output growth that led to underutilization of capital in capital-intensive industries. The declining rate of innovative output growth in turn is attributed to the business cycle, foreign competition, and higher energy prices.

¹³This industry is defined as Standard Industrial Class 28, excluding the drug industry (SIC 283).

Table 6-5. Introduction of innovations in chemical technologies

Period	Chemical products	Chemical processes	Equipment	Process instruments
Rate of introduction of innovations				
Average number per year				
1967-73	322.3	39.0	105.0	29.6
1974-79	39.0	32.3	54.7	18.2
1980-82	64.0	34.7	101.3	54.0
Fraction of innovations that are "radical innovations" or "major technical changes" in each period				
Percent				
1967-73	0.8	8.1	6.0	14.5
1974-79	0.4	8.0	0.6	10.1
1980-82	0.0	6.7	1.3	5.6

SOURCE: Alok K. Chakrabarti, "Trends in Innovation and Productivity: The case of chemical and textile industries in the U.S.," paper presented at the INSEAD Conference, July 7-9, 1987

Science & Engineering Indicators—1987

hancing.¹⁰ These innovations would not ordinarily lead to savings in capital and labor, and would not contribute to productivity. The decline in productivity-enhancing process innovations was thus even greater than 18 percent. The period from 1980 to 1982 was too short (and too turbulent economically) to permit definite conclusions to be drawn. Still, it seems that a recovery in innovation may have occurred, corresponding to the observed recovery in productivity.

Each of these innovations was also rated by experts in terms of its degree of novelty. Four ratings were permitted: radical innovation, major technical change, improvement of existing technology, and imitation of existing technology. The two highest ratings were combined in order to show trends in high-quality innovations as a supplement to the trends in the total number of innovations. (See table 6-5.)

Except for process innovations, the trend is downward, with each time period showing fewer high-quality innovations than the previous one. Some of this may be because experts rated more recent innovations lower since there had not been sufficient time to demonstrate the innovations' importance. Still, the general downward trend seems to be fairly pronounced. A lower quality of process, equipment, and instrument innovations may also have contributed to a lowering of chemical industry productivity—or may do so in the future.

Within the textile industry,¹¹ there was no drop in productivity in the 1970's. This is apparently due to the continued introduction of equipment innovations. (See table 6-6.) Equipment and instrument innovations usually originate with supplier companies, rather than with textile companies themselves. Similarly, fiber, finish, and dye innovations normally come from chemical companies. The role of textile mills' own R&D is to adapt these innovations for their own production purposes, to

work with suppliers in major development of equipment and instruments, and to produce textile process innovations.

Some decrease is shown in process, fiber, and instrument innovations. Fiber innovations have had a considerable effect on industry productivity in that the newer manmade fibers require far fewer processing steps and can be spun and woven much more rapidly than natural fibers. These productivity-improving fibers had already been developed before the drop in textile fiber innovation in the 1970's. Moreover, the textile industry—unlike the chemical industry—has had a relatively low share of innovations devoted to energy saving and pollution abatement as opposed to product quality and productivity enhancement.¹² This would also tend to promote the productivity performance of textiles as compared with chemicals.

A substantial drop is shown in the quality of innovations in fibers and processes. (See table 6-6.) This drop reinforces that in the total number of innovations. If productivity in this industry has not yet been affected by these trends, it may be in the future.¹³

Since textile equipment innovations are important to the productivity of that industry, a separate study was done of the origins of recent developments in weaving equipment.¹⁴ About 9 percent of weaving equipment innovations introduced from 1970 to 1984 were by American companies. (See table 6-7.) About twice as many were from Japan. This is in spite of the fact that the meetings at which the new equipment was displayed were largely American, so that—if anything—the data would favor American equipment.

¹⁰Bailey and Chakrabarti (1985), p. 619.

¹¹The most important innovations from the standpoint of productivity—those related to equipment and instruments—unfortunately could not be given consistent ratings.

¹²Data were obtained from a collection of textile trade show bulletins. See Chakrabarti (1987).

¹³Chakrabarti (1987).

¹⁴This is defined as SIC 22.

Table 6-6. Introduction of innovations in textile technologies

Period	Fibers	Dyes	Finishes	Processes	Equipment	Instruments
Rate of introduction of innovations						
Average number per year						
1967-73	15.0	109.1	117.7	16.2	134.5	53.8
1974-79	10.7	158.2	99.2	14.2	140.5	44.3
1980-82	3.7	89.0	68.0	9.3	154.3	37.2
Fraction of innovations that are "radical innovations" or "major technical changes" in each period						
Percent						
1967-73	28.5	0.0	0.2	12.4	—	—
1974-79	4.7	0.0	0.3	3.5	—	—
1980-82	0.0	0.0	0.0	0.0	—	—

SOURCE: Alok K. Chakrabarti, "Trends in Innovation and Productivity: The case of chemical and textile industries in the U.S.," paper presented at the INSEAD Conference, July 7-9, 1987.

Science & Engineering Indicators—1987

Table 6-7. Major weaving equipment innovations introduced between 1970 and 1984, by country of innovating company

Country	Number of innovations
Total	152
Japan	27
Switzerland	21
Italy	20
West Germany	17
Czechoslovakia	14
United States	13
Belgium	11
Spain	10
France	6
United Kingdom	6
Ireland	5
Soviet Union	1
Sweden	1

SOURCE: Alok K. Chakrabarti, "Trends in Innovation and Productivity: The case of chemical and textile industries in the U.S.," paper presented at the INSEAD Conference, July 7-9, 1987

Science & Engineering Indicators—1987

REFERENCES

- Bailey, M.N. and A.K. Chakrabarti, "Innovation and Productivity in U.S. Industry," *Brookings Papers on Economic Activity*, Vol. 2:1985, pp. 609-639.
- Basberg, B.L., "Foreign Patenting in the U.S. as a Technology Indicator: The Case of Norway," *Research Policy* 12 (1983), pp. 227-237.
- Bosworth, D.L., "The Transfer of U.S. Technology Abroad," *Research Policy* 9 (1980), pp. 378-388.
- Business Week*, "A Deepening Commitment to R&D," (July 9, 1984), pp. 64-78.
- Carpenter, M.P., E. Narin, and P. Woolf, "Citation Rates to Technologically Important Patents," *World Patent Information* (1981), pp. 160-163.
- Chakrabarti, A.K., "Trends in Innovation and Productivity: The Case of Chemicals and Textiles in the U.S.," paper presented at INSEAD conference, July 7-9, 1987.
- Dibner, M.D., *Biotechnology in the United States—A Report to the NSF Science Indicators Unit* (Research Triangle Park, NC: North Carolina Biotechnology Center, 1986).
- Griliches, Z., "Productivity, R&D, and Basic Research at the Firm Level in the 1970's," NBER Preprint No. 721 (Cambridge, MA: National Bureau of Economic Research, Inc., 1986).
- Griliches, Z., A. Pakes, and B.H. Hall, "The Value of Patents as Indicators of Inventive Activity," Working Paper No. 2083 (Cambridge, MA: National Bureau of Economic Research, Inc., 1986).
- Haklisch, C.S., H.J. Fustfeld, and A.D. Levenson, *Trends in Collective Industrial Research* (New York: New York University, Graduate School of Business Administration, 1984).
- Hansen, J.A., J.L. Stein, and L.S. Moore, *Survey of Industrial Innovation in the United States, Final Report* (Princeton, NJ: Audits and Surveys, February 1987).
- National Governors' Association, *Technology & Growth—State Initiatives in Technological Innovation* (Washington, DC: National Governors' Association, October 1983).
- National Science Foundation, "Plans for Company Funded Research and Development Show 12% Annual Increases Through 1985," *Science Resources Studies Highlights*, NSF 84-329 (Washington, DC: National Science Foundation, 1984).
- National Science Foundation, *Science and Engineering Personnel: A National Overview*, NSF 85-302 (Washington, DC: National Science Foundation 1985).
- National Science Foundation, "Growth in Company-Funded Research and Development Expected to Slow in 1987," *Science Resources Studies Highlights*, NSF 86-314 (Washington, DC: National Science Foundation, 1987).
- Pavitt, K., "Patent Statistics as Indicators of Innovative Activities: Possibilities and Problems," *Scientometrics* 7 (1985), pp. 77-99.
- Schiffel, D. and C. Kittl, "Rates of Invention: International Patent Comparisons," *Research Policy* 7 (1978), pp. 324-340.

U.S. Congress, Office of Technology Assessment, *Technology, Innovation, and Regional Economic Development: Encouraging High-Technology Development—Background Paper #2*, OTA-BP-STI-25 (Washington, DC: U.S. Congress, February 1984).

U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1987*, 107th edition (Washington, DC: 1986).

U.S. Department of Commerce, International Trade Administration, *An Assessment of U.S. Competitiveness in High Technology Industries* (Washington, DC: February 1983).

U.S. Patent and Trademark Office, Office of Technology Assessment and Forecast, "Review and Assessment of the OTAF Concordance Between the U.S. Patent Classification and the Standard Industrial Classification Systems: Final Report," January 1985.

Venture Economics, Inc., *Venture Capital Investment and Initial Public Offering Trends: 1984-85*, special report to the National Science Foundation (December 1985).

Chapter 7

The International Markets for U.S. Technology

The International Markets for U.S. Technology

HIGHLIGHTS

- *In 1986, the United States imported more high-technology products than it exported.* Imports of high-technology products were \$75.1 billion, while exports were \$72.5 billion. This was the first time ever that the United States had experienced a trade deficit in high-technology products. (See p. 124.)
- *Exports make up a larger part of the markets for U.S. producers of high-technology products than for producers of lower-technology products.* In 1984, more than 16 percent of U.S. high-technology products were exported, compared to only 5 percent of lower-technology manufactured products. Exports accounted for more than 20 percent of aircraft and parts shipments in 1984, and more than 30 percent of office and computing machines shipments. (See p. 124.)
- *Direct investment abroad by U.S. corporations has fallen in real terms since 1980.* Furthermore, U.S. direct investment abroad has been more evenly distributed among host countries, with the United Kingdom and Canada receiving lower shares of U.S. direct investment, and Japan receiving a larger share. (See pp. 125-126.)
- *Foreign revenues—composed of sales by U.S. firm affiliates and U.S. exports—make up almost one-third of the total revenues of U.S. high-technology producers.* Almost one-half of the revenues for the office and computing machines industry came from foreign operations in 1983, with net sales by affiliates (excluding exports from parent to affiliate) accounting for more than 30 percent of total revenues. By contrast, less than 20 percent of total revenues in non-high-technology industry were accounted for by foreign sales. (See p. 127.)
- *U.S. receipts and payments for the sale of patent licenses have remained approximately constant in real terms since 1972.* Payments have tended to equal about one-fifth the level of receipts, showing that U.S. firms have been far more active sellers of technology than purchasers. The funds received from these transactions are small compared to other foreign sources of income, totaling about one-tenth of 1 percent of total foreign revenues. (See pp. 130-131.)
- *U.S. firms have tended to purchase technology licenses from Western Europe, and to sell licenses in Japan.* In 1982, Japanese nationals made more than one-third the payments received by U.S. firms, but received only about one-sixth the payments by U.S. firms. In contrast, the United Kingdom accounted for one-tenth of payments to U.S. licensors, but received about one-quarter of payments by U.S. firms. The funds received from Japanese technology purchasers were about eight times as great as U.S. technology purchasers from Japan. (See pp. 131-132.)
- *The United States continues to be the world's leading exporter of high-technology products.* In 1984, the United States accounted for more than 26 percent of high-technology exports by the world's leading economies (about the same share as in 1975); Japan accounted for about 22 percent of high-technology exports, as compared to 12 percent in 1975. (See p. 134.)
- *The U.S. share of the important aircraft and parts and market has fallen sharply, while its share of the office and computing machines market has increased.* In the aircraft industry—which accounted for 20 percent of U.S. high-technology exports in 1984—the U.S. share of exports fell from more than 60 percent in 1975 to 47 percent in 1984. In contrast, the office and computing machines industry accounted for 22 percent of U.S. high-technology exports; this represented a growth in the U.S. market share from 30 to 36 percent between 1975 and 1984. (See p. 134.)

A major share of the U.S. research and development (R&D) effort is accounted for by private firms using private funds. The presumed goal of these investments in science and technology (S/T) is to develop a technological advantage that can be exploited profitably through either (1) the sale of products and services and/or the use of processes that perform new jobs, or perform old jobs better or less expensively; (2) the production of existing goods and services at lower cost; or (3) the provision of such technological expertise to other firms. Firms' willingness to undertake expensive and risky R&D pro-

grams thus depends in part on their access to markets in which the resulting innovations can be diffused and exploited. This chapter considers indicators that identify these markets for technology, and that show how the channels U.S. firms use for the international diffusion of technology vary over time and by industry. The variance of the U.S. experience with that of other countries also is presented.

The functioning of international markets for science and technology is important for many reasons. At the most abstract level, well-functioning markets and intel-

lectual property systems theoretically encourage an appropriate division of effort and specialization at both the national and international levels; this promotes a larger output of technological improvements, and ultimately increases the national welfare.

There are also more concrete reasons for observing the channels through which technologies are diffused. First, the health of the domestic economy is directly related to the flow of new technologies. This flow is in part a function of the flexibility of those markets where innovation is taking place—i.e., markets where new and improved products, processes, and services are being bought and sold. Second, private R&D investment and other methods of financing the innovation process depend on firms' access to markets for the resulting new products and services, and on their expected success in earning sufficient returns on the R&D investments to warrant further such investments. Third, the way in which a firm takes an innovation to market may affect the future ability to compete—both for that firm and for other U.S. enterprises. Finally, government policies may unintentionally either harm or help an unrelated S/T effort by restricting the markets through which technologies diffuse. For example, policies reflecting the national security interest in restricting technology transfers to the Soviet bloc may affect the ability of U.S. firms to exploit a technological advantage elsewhere in the world. This in turn may reduce their willingness and ability to pursue innovative programs in the future.¹

The primary goal of this chapter is to bring together several data sets that describe the markets for technology. Many of these data sets serve an important secondary function: in describing the activities of U.S. firms in the international marketplace—particularly in the high-technology areas—they indicate the strength of U.S. firms and of the U.S. economy versus foreign competitors.

This competitiveness is a difficult but important concept, embodying the widespread concern regarding the ability of U.S. producers to export, compete against imports, and operate successfully in foreign countries. Skilled and timely exploitation of emerging technological possibilities clearly contributes to the Nation's competitiveness by generating lower costs and both new and higher-quality products. Note, however, that there are other important factors, and that the precise contributions of technology, research and development, workforce skills, and other elements cannot easily be separated or quantified. Nonetheless, examining U.S. firms' performance in the international marketplace provides some indications of the strength, sources of weakness, and importance to the total U.S. economy of the Nation's S/T system.

Research and development are expensive activities; they require firms to commit substantial resources over extended periods of time, and to assume the risk that these investments may never produce profits. The fact that the business sector supports about one-half of the total U.S. R&D effort (see appendix table 4-1) validates

the belief that these investments (1) are necessary for maintaining competitive viability, (2) will—on average—produce returns at least as high as those available from alternative investments, and (3) will sometimes deliver dramatic financial returns.

Profitable international diffusion of an innovation—whether through exports, affiliate sales, or licensing to a foreign producer—helps to finance and justify the innovator's R&D expenditures and to stimulate other investments in the innovation. The following section examines these three principal channels through which technological innovations are commercialized and subsequently transferred and exploited overseas.

THE INTERNATIONAL DIFFUSION OF TECHNOLOGY

As mentioned above, there are three principal channels for the international diffusion of technological improvements. First, many innovations take the form of goods which can be produced in the innovator's home country and exported. Second, the innovator can invest in production facilities overseas to exploit the process/product innovation by operating a subsidiary. Third, if the innovation is patent protected—or there is a set of plans, procedures, drawings, etc., enabling an independent firm to replicate the innovation—the innovator may sell licenses to foreign firms.

For each of these channels, the following addresses three main issues of concern:

- How successful have U.S. firms been in their efforts to exploit technological advantages in the international marketplace?
- How has this participation changed in terms of the main channels of involvement?
- How does this involvement differ by industry?

International Trade in High-Technology Products

Emerson advised that if one can "make a better mousetrap than his neighbors, though he builds his house in the woods the world will make a beaten path to his door." The sale abroad of "better mousetraps" continues to provide an important motivation to American inventors. Moreover, U.S. success in exporting products linked to invention and innovation is a significant indicator of the strength of the economic ties linking the United States to the international S/T system.

About 43 percent of U.S. exports of manufactured products can be classified as high technology. (See appendix table 7-1.) Thus, a great deal of trade is not directly linked to R&D, invention, or innovative activity. For instance, the U.S. may retain a competitive edge for some products because of such natural advantages as access to mineral deposits or a favorable climate; for others, there may be a historical advantage in the necessary capital equipment; in still other cases, political links to trading partners may be significant.

Ideally, then, to analyze the role of science and technology in international trade, the impact of R&D—or

¹See National Academy of Sciences (1987).

measures of other components of the S/T effort—would be statistically analyzed to distinguish them from other variables affecting trade performance. However, fluctuations in macroeconomic variables (particularly interest rates and exchange rates between U.S. dollars and our competitors' currencies) have tended to overwhelm the statistical influence of R&D and other variables related to the S/T effort.² It therefore becomes necessary to rely on somewhat cruder methods.

Researchers have used a number of means to identify individual industries or product groups as "research intensive," or "high technology." These methods usually employ some measure of the R&D effort undertaken in the industry or product group, normalized for industry size.³ However, in some industries, the relevant R&D is performed internally; in others, firms depend on the innovations of those upstream suppliers that provide input to their production processes. To address this complicated technological structure, the U.S. Department of Commerce (DOC) uses an input-output table to allocate the applied research and development expenditures of intermediate-goods producers among the appropriate final-goods producers. This allocation, when normalized by shipments, permits identification of groups of products whose total R&D intensity are significantly higher than that of other products. These product groups are known collectively as the DOC-3 high-technology products.⁴ (See appendix table 7-2.)

Until 1986, the United States maintained a consistent trade surplus for the identified high-technology product groups, while generally importing more than it exported of other manufactured products. Since 1980, however, the U.S. high-technology trade surplus has declined substantially, dropping from about \$30 billion (at 1982 prices⁵) in 1980 to \$3 billion in 1985. In 1986, the United States experienced its first trade deficit in high-technology products, with exports of \$72.5 billion and imports of \$75.1 billion. (See figure O-26 in Overview and appendix table 7-1.) This deficit reflects the steady increase in U.S. imports of high-technology products: these grew in real terms at an average annual rate of about 12 percent from 1980 to 1986, while exports remained more or less constant.

For all but 1 of the last 16 years, the U.S. has imported more than it has exported of products outside the high-technology groups; in the last 6 years, this deficit has increased sharply as exports have fallen and imports have risen. This demonstrates the increasingly competitive markets for *all* U.S. manufactured goods, a condition affecting both high-technology producers and—somewhat less dramatically—the non-high-technology sector.

²See Hilke and Nelson (1987).

³R&D expenditures as a percentage of total sales, and scientists and engineers employed in R&D as a percentage of total employment are two prominent examples of this approach. See Boretsky (1982) and Kelly (1976).

⁴See Davis (1982) and U.S. Department of Commerce (1983).

⁵Since there is no deflator available specifically for high-technology trade, nor for exports in general, current-dollar data were adjusted using the gross national product (GNP) deflator. Trends in constant-dollar terms should therefore be treated as approximations.

There is a continuing shift in the U.S. comparative advantage away from traditional manufactures and toward more R&D-reliant products. However, the tendency of high-technology and non-high-technology trade balances to move in the same directions (see figure O-26 in Overview and appendix table 7-1) reflects the significance of other factors—such as the combination of strong demand at home, relatively weak demand abroad, and the strength of the U.S. dollar vis-a-vis the currencies of U.S. competitors—confronting high-technology and non-high-technology producers alike.

Data on trade in high-technology products have been used to assess technology's contribution to economic competitiveness.⁶ But international trade in products is more than an arena for testing the efficacy both of U.S. innovation and U.S. policies to promote that innovation. Trade is itself an integral part of the science and technology system. As such, it provides a means for technology diffusion and for amortizing private investments in R&D. To examine trade as a channel for the spread of technology, data on trade in high-technology products must be analyzed.

Exports make up a relatively large part of the markets for U.S.-produced high-technology goods, compared to non-high-technology products. (See figure O-27 in Overview and appendix table 7-2.) In 1984, the most recent year for which data are available, more than 16 percent of high-technology shipments were exported, while only 5 percent of other manufacturing products were sold abroad.

Of all groups of high-technology products, three—aircraft and parts, communications equipment and electronic components, and office and computing machines—account for a large and increasing share of all high-technology exports (68.1 percent in 1986, up from 59.9 percent in 1978); as well as of all manufacturing products (29.1 percent in 1986, 21.5 percent in 1980). Taken together, these three product groups are even more dependent upon foreign export markets than are all high-technology products combined, with exports accounting for about 20 percent of shipments in 1985. (See appendix table 7-2.)

The three product groups also were particularly intensive in their R&D performance. In 1985, company-funded R&D expenditures in the industries associated with these products were about \$19 billion, or almost 37 percent of the total industry-funded R&D effort in the U.S.⁷ This measure, however, probably understates the importance of these industries to the U.S. commercial R&D endeavor, as these industries both provide important markets for various high-technology inputs and encourage R&D expenditures in various supplier industries.

The data suggest that increased commercial R&D activities accompany increased exports. While it cannot be concluded that increased R&D leads to increased exports (or vice-versa), there are reasons to believe that the two

⁶See Finan, Quick, and Sandberg (1986).

⁷See National Science Foundation, *Research and Development in Industry* (1986). Document is distributed on diskette.

are mutually reinforcing. Successful R&D improves competitiveness in foreign markets, and access to foreign markets makes innovative activities potentially more profitable; this in turn encourages and provides resources for private investment in R&D.

International Direct Investment

Possession of a technological advantage does not necessarily mean that a firm will actively export goods, or that the export of goods will be the sole—or even the primary—way in which the firm exploits its advantage. Rather, technologically advanced firms frequently operate foreign subsidiaries and affiliates. For, although exporting products is typically an attractive approach to the international marketing of a technological advantage, tariffs and other barriers to trade in goods frequently make direct investment a more profitable choice.⁸

The choice of channels for foreign market penetration may be related to the technology's age, with innovations initially exploited through exports and production moving offshore as the product or process matures.⁹ Relative costs of production in the U.S. and in foreign countries are also a factor: if these costs are substantially lower overseas, production will increasingly be transferred to the foreign affiliate, and affiliate sales will substitute for exports. Overseas direct investment may also be a response to trade barriers—if imports into a country are restricted, a firm may instead set up production facilities in that country.¹⁰ Thus, detailed information on technologies' age and other characteristics, production costs, and countries' tariffs and other trade barriers would enable assessment of the importance of technological versus legal and political influences on diffusion channels. In the current absence of such detailed information, however, analysis of the trade and diffusion of technology and high-technology products is limited.

The possession of some advantage is a widely acknowledged rationale for establishing overseas subsidiaries.¹¹ This advantage may involve access to superior technology, or such other firm-specific assets as brand-name advantages and distribution networks; these latter are not easily sold or otherwise transferred to other firms.¹²

It is typically less costly to transfer technology *within* firms than *between* firms.¹³ The multinational corporation that operates production facilities in several countries may thus be seen as a vehicle for the international exploitation of a technological advantage.

Data on international direct investment in manufacturing—particularly in high-technology industry—serve a similar function to data on trade. First, they reflect the technological advancement of U.S. firms as compared to that of foreign rivals. Second, the data reflect the use of

this channel (international direct investment) for technology diffusion both by U.S. firms abroad and by foreign enterprises operating in the United States.

The analysis here stresses the activities of multinational enterprises in manufacturing.¹⁴ It concentrates on the international holdings and operations of U.S. manufacturing enterprises, although some new data on direct investment in certain technology-related service industries are also explored.

U.S. Direct Investment Abroad. The U.S. direct investment position measures the book value of U.S. investors' equity in and outstanding debt with affiliated firms overseas.¹⁵ It provides an indication of both the level and location of this sort of international activity by U.S. firms.

U.S. holdings of overseas affiliates in the manufacturing industries increased steadily until the middle of the 1970's, after which the net worth of these holdings fluctuated, declining in real terms since 1980.¹⁶ (See figure 7-1). This pattern was also followed by the two major industry groups comprising the bulk of high-technology activity for which detailed data are available: chemicals and allied products and machinery (which combines the machinery—except electrical—and electric and electronic equipment industry groups).

This reduction in the real value of direct investment holdings reflects an actual withdrawal of capital by U.S. parent companies, combined with a reduced rate of increase of reinvested earnings, a reduced rate of investment in new capital, and capital losses—including those due to declines in the net value of the foreign currency denominated assets of foreign affiliates.¹⁷ The overall direct investment position therefore can only be interpreted as a general indicator of the activity level of U.S.-based multinationals, and of the potential size of this channel for the international diffusion of technology. After a long period of steady growth, this channel has apparently shrunk in the last few years.

The geographical location of U.S. investments in overseas subsidiaries has changed substantially over the

⁸Rationales other than technological advantage are important for the existence of multinational enterprise in other industries. For example, the petroleum industry—which accounted for almost one-quarter of all U.S. direct investment abroad in 1986, but which performs little R&D—invests abroad primarily to gain access to crude petroleum deposits; only about 15 percent of its investment is related to wholesale or retail marketing activities. See U.S. Department of Commerce (1987b), p. 83.

Wholesale and retail trade are two other industry groups where there is a high level of U.S. direct investment abroad. While this investment may be related to the superior technologies embodied in the goods that the trading affiliates are selling, this technological component is accounted for in measures of the manufacturing activity when these goods are actually produced—either through measures of U.S. exports of high-technology products (some of which supply the trading affiliates), or in U.S. investments in manufacturing facilities overseas.

¹⁰"Affiliates" are defined as firms in which the reporting U.S. parent holds an interest of at least 10 percent. See U.S. Department of Commerce (1985a), p. 4.

¹¹Data are converted into constant terms using the GNP deflator. As the data are already converted into U.S. dollars using the currently prevailing exchange rates, which reflect many factors besides the relative changes in prices in the different countries, the use of any single U.S. price deflator can only approximately correct the effects of inflation.

¹²See U.S. Department of Commerce (1985b), p. 31.

⁹See Mansfield, Romeo, and Wagner (1979).

¹⁰See Vernon (1966) and Hufbauer (1966) for early discussions of the "product cycle."

¹¹See Horst (1971), pp. 1059-1072.

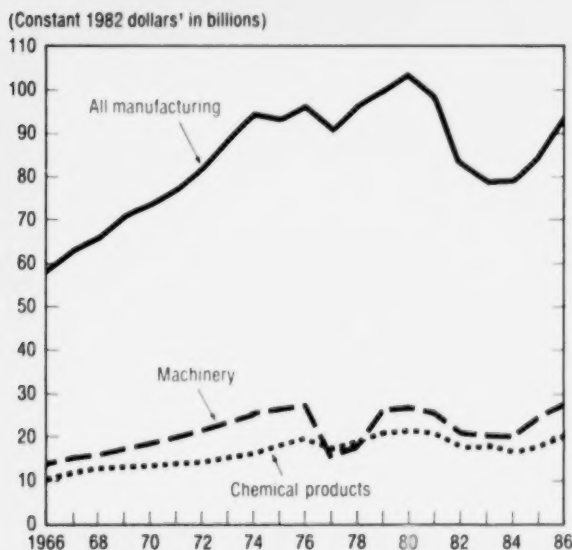
¹²Caves (1982), pp. 3-12 and 196-200, contains discussion and many references to theoretical and empirical work.

¹³See Teece (1986b), pp. 21-45.

¹⁴See Teece (1977).

Figure 7-1.

U.S. direct investment position abroad, manufacturing industries



¹GNP implicit price deflators used to convert current to constant dollars.

See appendix table 7-3.

Science & Engineering Indicators — 1987

years. (See figure 7-2.) In 1966, U.S. direct investment in Canadian and British affiliates made up almost one-half of the total U.S. direct investment position in manufacturing; by 1984, this combined investment had declined to 36 percent. West Germany and France each were hosts to more than twice as much U.S. direct investment as Japan in 1966 for the manufacturing industry as a whole, and about twice as much in the machinery and chemical industries. By 1984, however, Japan and France received similar amounts of U.S. direct investment, while U.S. investments in West Germany continued to increase.

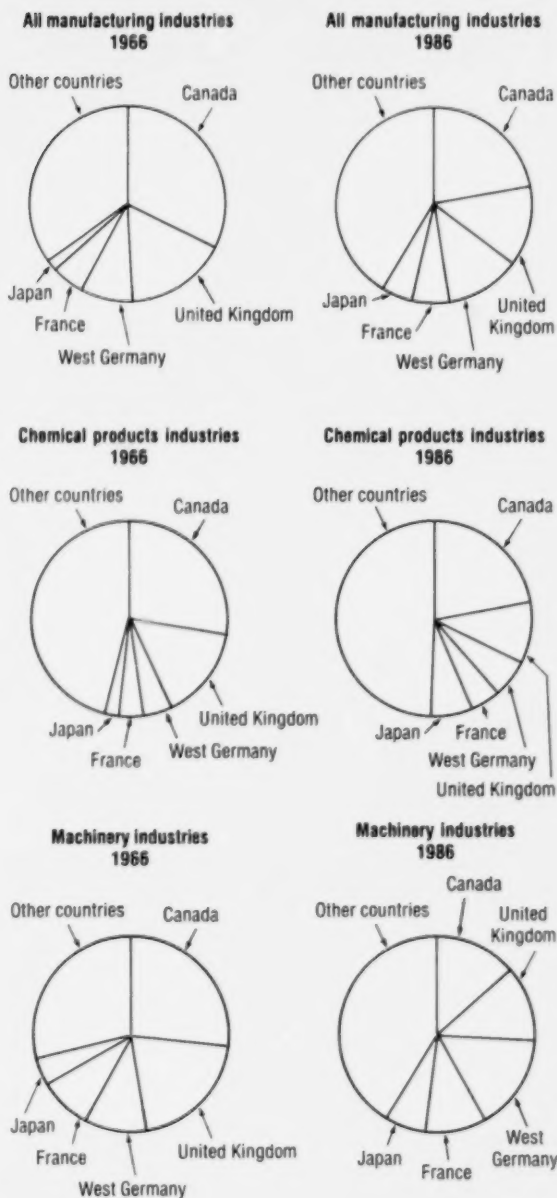
Operations of Foreign Affiliates of U.S. Parent Firms. More detailed information on overseas direct investment is available from a new survey of the operations of both U.S. multinationals' foreign affiliates and U.S. parent firms. This survey covers income statement and balance sheet data for parents and affiliates, broken down by industry of both parent and affiliate.¹⁸

This more detailed by-industry classification permits an examination of direct-investment-related activity in specific high-technology manufacturing industries, as

¹⁸Reports on the financial structure and operations of non-bank affiliates of non-bank U.S. companies were collected from each firm with a non-bank foreign affiliate whose assets, sales, or net income exceeded \$10 million. In 1984, 1,221 U.S. manufacturing firms reported on the activities of more than 11,000 foreign affiliates. When classified by affiliate primary industrial activity, there were 6,869 affiliates in manufacturing industries, as well as 288 in three technology-related service industries. See U.S. Department of Commerce (1986a).

Figure 7-2.

U.S. direct investment position abroad, distribution by host country, major industry groups



See appendix table 7-3

Science & Engineering Indicators — 1987

well as in several technology-related service industries. In addition, the survey's coverage of current operations (income statement data) is closely related to the current competitive strengths and weaknesses of the parent and affiliate firms, while the balance sheet information (discussed above) concentrates on longer-term decisions

about the location and financial structure of parent firms' foreign activities.

The discussion here is based on data reported by industry of affiliate for the manufacturing industries corresponding to the DOC-3 high-technology product groups. (See appendix table 7-4.) It also covers three technology-related service industries—computer and data processing services; research and development and testing laboratories; and engineering, architectural, and surveying services. Firms in these high-technology manufacturing and technology-related service industries are the ones most closely involved with the international marketing of technological advantages.

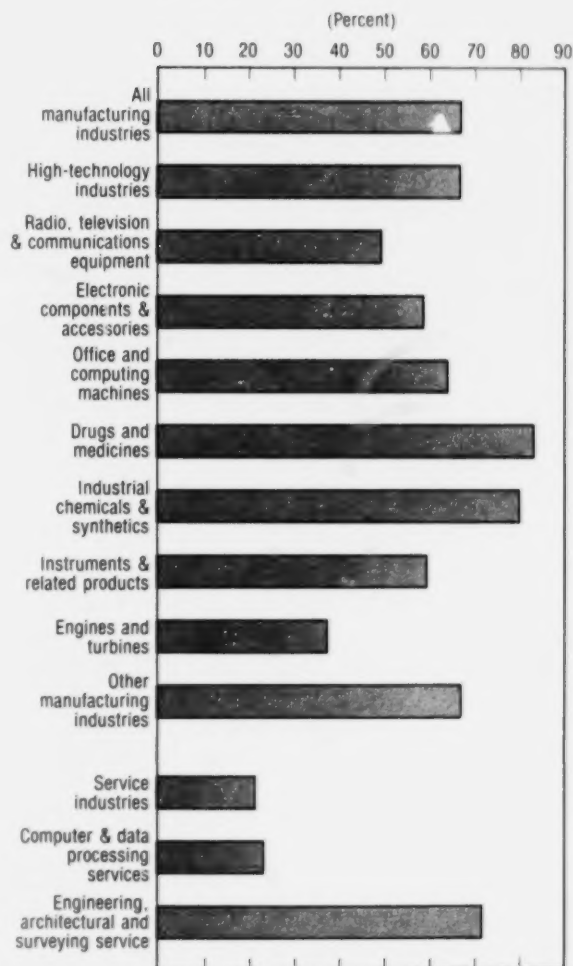
Sales of U.S. affiliates can be used to evaluate the importance of the direct investment channel for exploiting U.S. technological advantages. This is determined by calculating the ratio of net affiliate sales to total foreign revenue.¹⁹

Sales by overseas affiliates comprise a large part of overseas revenues for U.S. manufacturing (both high-technology²⁰ and non-high-technology) industries. The entire "other transportation equipment" direct investment industry class (DIIC)—which includes aircraft and parts, guided missiles and spacecraft, and several other transportation industries—accounted for less affiliate sales than any of the high-technology industries considered here except the engines and turbines industry.²¹ The electronic components and accessories industry and the radio, television, and communications equipment industry also had relatively low net affiliate sales. (See figure 7-3.)

Access to foreign markets through direct investment is slightly more important for non-high-technology industries than for that of high-technology industries. (See figure 7-3.) However, in comparing affiliate sales to total corporate revenue,²² this trend is reversed. In figure 7-4, the share of total revenues accounted for by net affiliate sales was almost twice as great in the group of

Figure 7-3.

Sales by foreign affiliates of U.S. corporations as a percent of foreign revenue: 1984



See appendix table 7-4

Science & Engineering Indicators — 1987

¹⁹Net affiliate sales are calculated as affiliate sales less parent firm exports to affiliates—this avoids counting twice goods exported for resale by affiliates. The sum of net affiliate sales and exports by the domestic industry is a measure of the industry's total foreign revenue.

²⁰The industries defined here as high-technology are those whose direct investment industry classifications (DIIC) correspond to the DOC-3 high-technology product groups, with the following exceptions. There are no DIICs for guided missiles and spacecraft, aircraft and parts, or ordnance and accessories. Industrial inorganic chemicals and plastic materials and synthetics are combined with industrial organic chemicals (not a DOC-3 high-technology product) to form the industrial chemicals and synthetics DIIC. See Davis (1982) and U.S. Department of Commerce (1985a), pp. 439-459.

²¹See U.S. Department of Commerce (1987b), tables 2 and 17.

²²As in the discussion of high-technology exports, the sales figure used is shipments in selected industries. Total foreign revenues are the sum of exports of the corresponding high-technology products, plus sales of affiliates operating in the selected high-technology industries, minus imports from parents of the surveyed affiliates. The sum of net affiliate sales plus exports is then taken as a percentage of total revenue. This procedure is not correct in a strict accounting sense, as the exports are calculated on a product basis, while affiliates are classified by their primary economic activity. This activity differs in many cases from that of the parent companies, which is the classification of the shipments data.

high-technology industries as in other manufacturing industries. Moreover, none of the individual high-technology industries for which data are available received a lower share of revenue from affiliate sales than the 11.5 percent of the non-high-technology manufacturing industries. Overseas affiliates are particularly important to firms in the office and computing machines and drug and medicine industries, where net affiliate sales accounted for more than 30 percent of total revenue in 1983.

The importance of foreign markets as a whole to the U.S. high-technology enterprise is indicated by comparing total sales abroad to total domestic sales. In 1984, foreign sales, made up of net affiliate sales plus exports, were equivalent to almost 32 percent of total shipments in

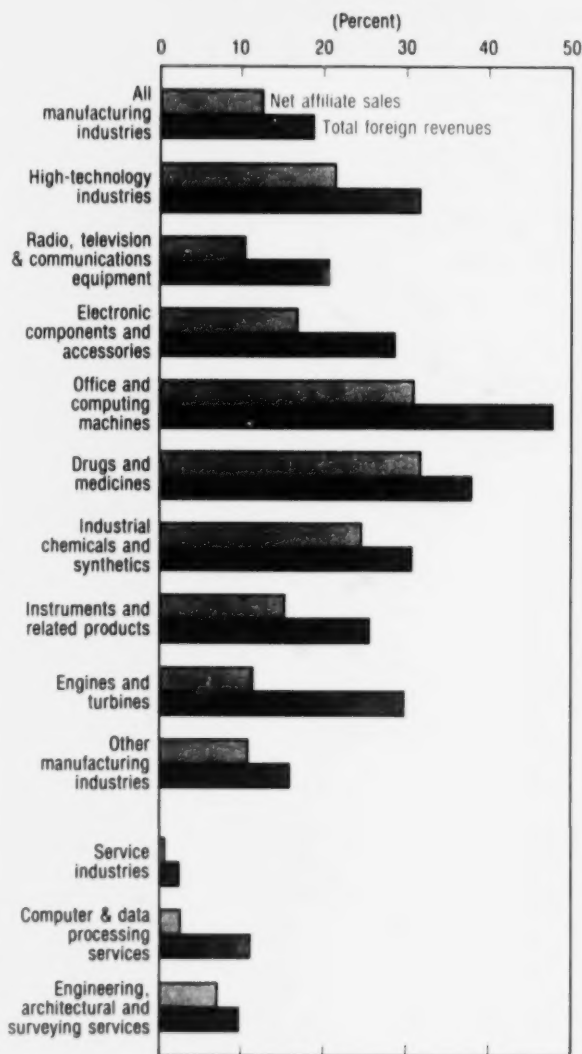
seven high-technology industries.²³ (See figure 7-4.) The office and computing machines industry led these industries with about 48 percent of shipments. The radio, television, and communications industry—with 21 percent of revenues from foreign sources—was the least “international” of U.S. high-technology industries. In contrast, non-high-technology manufacturing industries made only about 16 percent of their sales to foreign customers.

Foreign Direct Investment in the United States. The United States is the world's single largest recipient of international direct investment. In 1984, the U.S. received about 21 percent of all international direct investment; this was primarily from other advanced industrialized economies.²⁴ Investment source and industrial location indicate the role such investments play in the international diffusion of technology. For example, do these foreign investments in the U.S. correspond to transfers of foreign-origin technology into the United States? Is technology a less important part of foreign investment in the U.S. than it is of U.S. investment overseas?

In 1986, foreign direct investment holdings in U.S. manufacturing industries were worth more than \$68 billion (at current prices). This represented an increase (in real terms) of 38 percent since 1981—an average annual growth rate of almost 7 percent. (See appendix table 7-5.) The distribution of these holdings by nationality of ownership is shown in figure 7-5; the great majority of these holdings belong to investors in the advanced industrialized countries.²⁵

Several features stand out in this distribution of holdings. First, while Japan has experienced great success in international competition in general (and in the development of technological expertise in particular), Japanese firms account for a very small share of total foreign direct investment in the United States. Even in the machinery industries (including computers and office machines; radio, television, and communications equipment; and electronic components and accessories—three industries where major Japanese participation might be expected and which accounted for 52 percent of the foreign direct

Figure 7-4.
Net affiliate sales and total foreign
revenues of U.S. corporations as a
percent of total revenue: 1984



See appendix table 7-4

Science & Engineering Indicators — 1987

²³The aircraft and parts and guided missiles and spacecraft industries are excluded from this analysis as data are not available for affiliate sales in these industries. It should be noted that exports alone of these products amount to more than 20 percent of shipments; including exports of these products in foreign revenues, and shipments from these industries in total revenues, leaves the ratio of high-technology revenues coming from foreign markets at more than 30 percent. (See appendix tables 7-2 and 7-5.)

²⁴See U.S. Department of Commerce (1984), pp. 45, 61, and updates from Office of Trade and Investment Analysis, International Trade Administration.

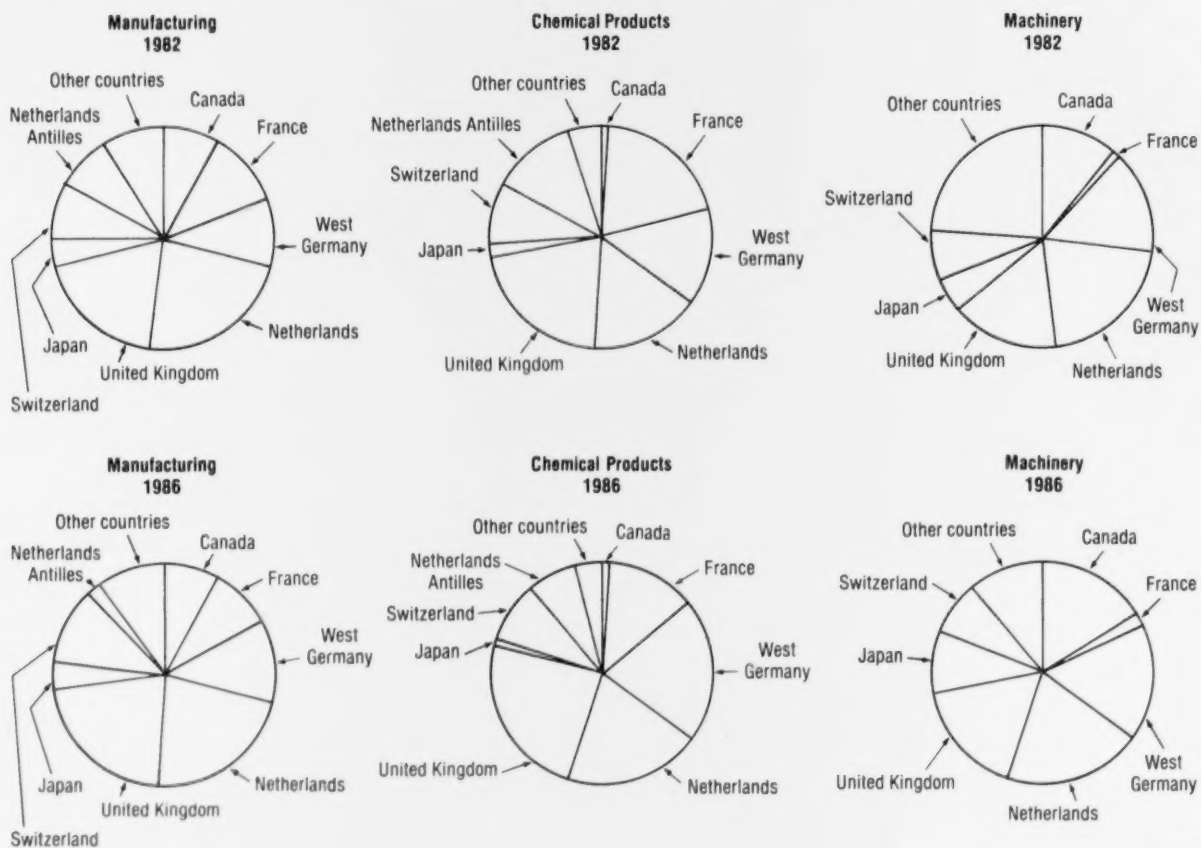
²⁵The substantial distribution attributed to the Netherlands Antilles includes large holdings by investors from other advanced industrialized countries (including the U.S.). However, even when tracing assets to the country of “ultimate beneficial owner,” the Netherlands Antilles remains an important source of foreign direct investment, since the majority of investing firms are largely incorporated in the Netherlands Antilles, and their ownership cannot be further identified. See Shea (1986).

investment position in machinery in 1986).²⁶ Japanese investors accounted for only 6.6 percent of 1985 foreign investment in the U.S.

The level of Japanese participation in foreign direct investment in the United States mirrors the relatively low levels of U.S. direct investment in Japan. This suggests cultural, linguistic, legal, or other barriers that block the operation of multinational business between the two countries. There are a number of other explanations for

²⁶See U.S. Department of Commerce (1987a), table 23, p. 98.

Figure 7-5.

Foreign direct investment in the United States in manufacturing, distribution by country: 1982, 1986

See appendix table 7-5

Science & Engineering Indicators — 1987

these apparently low levels of investment. For instance, some Japanese investment in manufacturing industries—particularly in the automobile industry—is classified as wholesale trade. This is because the industrial classification methodology is based on the enterprise's principal activity. Also, foreign direct investment in Japan was—at least until the late 1970's—restricted by policy; concurrent restrictions on Japan's outflow of capital made outside direct investment more difficult.

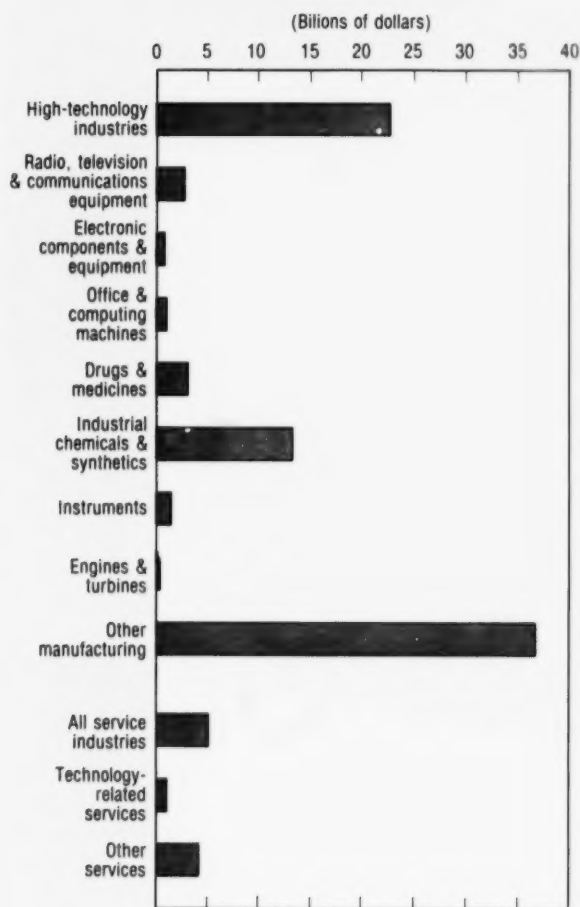
A second important feature of foreign direct investment is the relatively small role of Canadian direct investment. (See figure 7-5.) Although Canada is the most important host for U.S. direct investment abroad, and in spite of very strong cultural ties between the two countries, Canadians own a relatively small share of the foreign direct investment position in the United States. In contrast, the Netherlands is the largest source of foreign direct investment in U.S. manufacturing. This activity is broadly spread: Dutch investors account for major shares of the total foreign position in both chemical products

and machinery. Switzerland is another relatively small country with a major position in the United States; France, on the other hand, is somewhat less active (relative to its size) in the United States, particularly in machinery.

A detailed breakdown by industry is available for the total foreign direct investment position in the United States. Foreign investors are not particularly active in most of the high-technology industries, with combined direct investment holdings of about \$26 billion in 1986. (See figure 7-6 and appendix table 7-6.) More than one-half of this investment was in the industrial chemicals and synthetics industry. Non-high-technology industries account for almost two-thirds of total foreign direct investment in U.S. manufacturing industries, and about 80 percent of the foreign holdings in U.S. service industries.

The two countries that appear to offer the U.S. the closest competition in global markets for technology—West Germany and Japan—have smaller presences here than would be expected if direct investment in the United

Figure 7-6.
Foreign direct investment in the U.S.
manufacturing industries: 1986



See appendix table 7-6.

Science & Engineering Indicators — 1987

States were primarily a function of technological competitiveness. Furthermore, foreign direct investment in the United States is weighted toward those industries that, at least in the United States, are not high-technology. In contrast, the pattern of U.S. direct investment abroad seems to be strongly related to technological strength, or at least to research and development effort. This latter correlation is not unexpected, since industries where U.S. corporations put their greatest technological efforts—the high-technology industries—should offer fewer opportunities to foreign firms for profitable direct investment in U.S. production facilities.

Patent Licenses and Technology Agreements

The preceding sections have concentrated on commerce, primarily related to technology, where the exploiting firm has traded on its technological advantage

without actually selling control of the technology to other firms. The sale of high-technology products involves the export of so-called “embodied technology.” These products were selected because they reflect significantly greater R&D expenditures—both by the producing industries and by industries upstream—than do non-high-technology products. The sellers of these goods then trade upon the greater sophistication and serviceability of their products. In time, other firms—both at home and in other countries—imitate the innovator’s techniques, and the competitive advantage from technological innovation dissipates. There is thus a transfer of technology through two channels: (1) the technology-embodiment goods that are sold, and (2) the information these goods carry which ultimately permits a rival to copy or improve upon them.

There is also a twofold transfer of technology related to direct investment. First, the innovative firm sets up production of its technology-embodiment product in the market, creating a transfer of technology analogous to that accompanying high-technology product export. Second, there is a transfer of “disembodied technology.” In setting up production facilities, the investing firm brings a panoply of formal and informal knowledge (know-how) associated with the technology’s use. This know-how ranges from designs and blueprints to production experience and knowledge of appropriate marketing strategies. As with exporting, there is undoubtedly a leakage of technology to the firm’s potential rivals. Moreover, the wider the distribution of a good, the more likely it is to be seen by an imitator, and the more visible the market the imitator may hope to capture.

Exporting and investing abroad are very different approaches to the international transfer of technology, and are pursued to different degrees in different industries. However, both strategies have an important element in common: technology leakages to potential competitors are not deliberate, and those leakages that do occur are largely an inevitable result of successful marketing.

Exporting products and investing in production facilities abroad are not the only way in which firms can profit from their technological advantages. Firms also may simply sell their rights to an invention, and/or provide technical information on an invention’s production or use, to an independent firm. This latter firm will undertake the product’s improvement, production, and/or marketing, paying license fees and royalties to the original firm; these are frequently proportional to product sales.

Such arrangements have both advantages and drawbacks. On the positive side, the firm selling its technology may lack access to the resources necessary to fully exploit the technology, such as related technologies, raw material or capital resources, marketing expertise in the relevant country or industry, etc. Furthermore, firms may be able to exchange licenses with other firms, thereby gaining access to a new pool of knowledge.

On the other hand, by selling patent licenses and associated technical information and blueprints, the licensing firm makes the potential imitator’s job much easier. The licensor sells not just technical information, but also partial control over the technology. Science and technology are cumulative; advances typically require mastery of the existing art. A cost of patent protection is the information

that is disclosed in the patent document; if a license to the patent is also sold, the imitator need not wait for patent expiration to gain production experience. Additionally, the sale of nonpatent plans, specifications, operating procedures, and so on, further accelerates the imitator's mastery of the existing art.

To some extent, firms' receipts and payments of firms for patents and technical exchange agreements represent a pure indicator of technological prowess. Particularly between unaffiliated firms—where prices are set through some market-related bargaining process—they reflect only the exchange of technology, totally separate from individual products or a firm's internal characteristics. Thus uncluttered by other elements of competitiveness, these receipts and payments may be seen correctly as an "output" indicator—one of the few statistics describing the production and exchange of knowledge. However, while the data describing patent license sales and exchanges reflect technological merit, the problems associated with the underlying transaction suggest that they also be viewed as indicators of constraints upon technology transfer channels.

When possible, it is appropriate to examine receipts and payments associated with technology exchanges between independent firms, rather than between affiliates, since there is no reason to believe that the prices a firm sets for its internal transactions bear a close relationship to market values. Unfortunately, however, transactions between affiliates are not always reported separately from those between independent firms. When such combined data are used, it should be remembered that they may reflect a firm's internal accounting practices as well as technology transactions between firms.

Since 1972, both U.S. receipts and U.S. payments of royalties and fees associated with unaffiliated foreigners have remained more or less constant in real terms: receipts have fluctuated around \$1.5 billion at 1982 prices, and payments around \$300 million. (See appendix table 7-7.) During the last decade, U.S. receipts for technology have generally been about five times as great as payments.

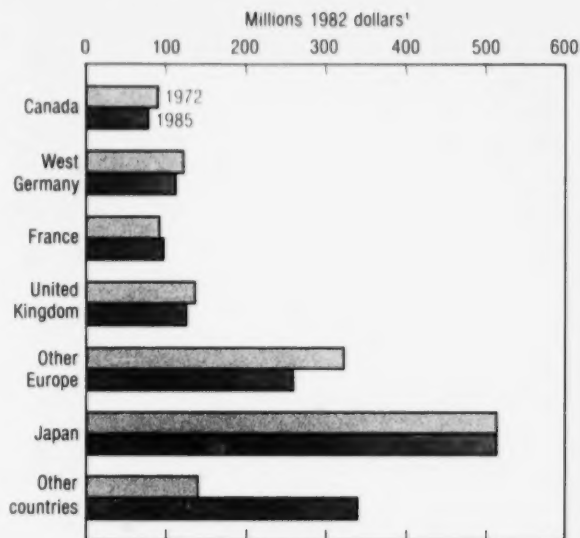
Compared to the other two channels for technology diffusion, licensing and other technology agreements are quite small, making up less than one-half of 1 percent of total foreign operations in 1984. (See appendix tables 7-4 and 7-7.) These data, however, represent a pure flow of technology. Technology transferred in this way provides a means for the foreign purchaser to overcome a technological lag; at the same time, the purchaser may improve its current ability to compete, as well as its ability to participate in later improvements of the products and/or processes involved. Sellers of such technology gain a percentage of sales in foreign markets that they may have been unwilling or unable to exploit either through exports or direct investment in those markets.

These bilateral transactions in patent licenses and other technology exchange agreements between U.S. firms and the unaffiliated nationals of particular countries thus provide a useful indication both of the nature of technology transfers between the two countries, and of the success the countries are experiencing in acquiring—and presumably using—the other's technology.

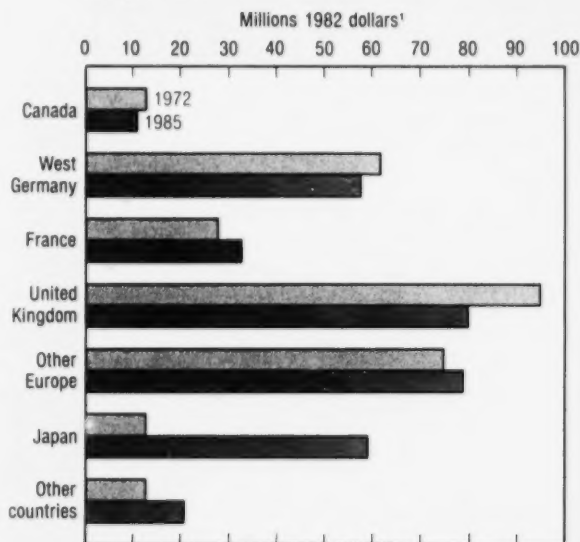
There is considerable variation in the technological relations between the United States and different countries. (See figure 7-7.) Japanese nationals in 1985 made more than one-third of the payments received by U.S. firms, but received only about one-sixth of U.S. payments. In contrast, nationals of the United Kingdom

Figure 7-7.

U.S. receipts of royalties and fees from unaffiliated foreigners: 1972 and 1985



U.S. payments of royalties and fees to unaffiliated foreigners: 1972 and 1985



¹GNP implicit price deflators used to convert current to constant dollars.

See appendix table 7-7

Science & Engineering Indicators — 1987

accounted for 8 percent of U.S. technology receipts, but received more than 23 percent of U.S. payments. U.S. receipts from U.K. nationals were about 55 percent greater than payments to the United Kingdom in 1985; in contrast, receipts from Japanese purchasers were more than 700 percent greater than payments. Overall, U.S. receipts were about 3.5 times as great as U.S. payments.

Given the size and strength of the U.S. science and technology system, the positive technological balance of payments between the United States and the rest of the world is not surprising. A surplus between the United States and even as technologically sophisticated a country as Japan is to be expected; however, the size of the U.S. surplus with Japan requires further analysis. Perhaps Japanese producers are superior at practical application of ideas and inventions; or U.S. firms are better at invention than innovation; or there are legal, political, or other obstacles that prevent U.S. producers from putting their inventions into practice, and that require the participation of Japanese licensees. There also may be other, more innocuous, reasons for the strong tendency of U.S. inventors to license their technologies in Japan.

The technology flows between the United States and Japan, however, are considerably less one-sided than they used to be. After accounting for inflation, U.S. technology receipts from unaffiliated Japanese entities have remained constant since 1972, while the level of payments in 1985 was more than 4.5 times as great as the 1972 level.

U.S. payments to technology sellers in the United Kingdom are larger than might be expected given the size of the British R&D endeavor. In 1983, United Kingdom R&D expenditures were less than one-half those made in Japan, and about two-thirds the level in West Germany; nonetheless, the U.K. was easily the largest recipient of U.S. technology payments. (See appendix table 4-1 for data on R&D expenditures.)

The close cultural and linguistic ties between the United States and the United Kingdom might explain the high level of British technology sales. But this explanation would also predict particularly large technology transactions between the United States and Canada, and a high level of U.K. purchases of U.S. technology—neither of which is in fact the case. For example, U.S. technology receipts from the United Kingdom are only one and one-half times as great as payments, so that the bilateral technological payments between the U.K. and the U.S. are closer to balance than are the payments between the United States and any other country.

Japan and the United Kingdom represent the extremes of the U.S. technology transaction activity (at least among the largest industrialized countries). Comparing these two sets of technology transactions shows that the U.S. both imports and exports disembodied technology, without an accompanying flow of goods or investments.

The total flows of receipts and payments of royalties and license fees include both new agreements and those made in previous periods which are still in force. A history of U.S. inventive strength, and the past willingness of U.S. inventors to transfer their technology to overseas entrepreneurs, may overshadow current efforts by U.S. firms to both import and adopt foreign

technology, and to use other channels to transfer and exploit their own advantages overseas. The U.S. data discussed above do not distinguish between new and old technology agreements, and thus may reflect this slow responsiveness to current conditions.

To partially rectify this difficulty, there is a recent Japanese government survey of the technology purchase and sale activities of Japanese firms. This has shed light on the year-by-year transactions between Japanese and U.S. firms (and between Japanese firms and nationals of the other large advanced industrialized countries). While these data reflect only some of each year's technology transactions between Japan and the rest of the world—and of course contain no information about transactions between the United States and countries other than Japan—they do provide additional details about the relatively high level of technology sales made by U.S. firms to Japan, as well as U.S. technology purchases from Japan.

Table 7-1 shows the share of new transactions in the total Japanese receipts from sales and payments for purchases of technology. Improvement in the Japanese technology bases should reduce Japanese purchases and increase Japanese sales relative to their historical levels. In fact, although there is considerable year-to-year fluctuation in the share of Japanese technology receipts and payments attributable to new agreements, the tendency seems to be in the opposite direction. As new Japanese technology purchases have increased (relative to the existing level of technology exchange agreements), the value of new Japanese technology sales has increased less rapidly than has the total of annual Japanese receipts from all technology agreements. Thus, there is little evidence that strong Japanese performance in developing commercial technology is being matched by licensing that technology to non-Japanese producers abroad, or by reduced purchases of technology licenses from foreign inventors.

Table 7-1. New agreements as a percent of total technology transfer agreements between Japan and the United States and other major countries: 1975, 1980, 1985

	1975	1980	1985
	Percent		
Technology sales to:			
United States	19	28	14
Other major countries	58	42	43
Technology purchases from:			
United States	7	13	11
Other major countries	8	9	13

See appendix tables 7-8, 7-9.

Science & Engineering Indicators—1987

TECHNOLOGY AND U.S. COMPETITIVENESS

Science and technology are not only influenced by the national and international trading system, but are also a source of competitive strength and success within that system. The contributions of research and development and other S/E activities to the Nation's economic performance—specifically to the ability of U.S. producers to compete in both domestic and international markets—are one of the rationales for Federal support of science and engineering. By examining data on the marketing of technological advantages, this section assesses S/E's contribution to trade performance, and identifies areas of U.S. strength and weakness as compared to other countries.

Technological proficiency does not guarantee success in the international marketplace. A firm also may need access to attractive financing packages, advertising and marketing skills, manufacturing expertise, etc. Without such complementary assets, better equipped imitating firms may be able to overtake the innovating firm, gaining the advantages ascribed to being "competitive."²⁷

This section discusses "competitiveness," broadly defined as the ability of U.S. firms to sell products abroad and in domestic markets. Two aspects of competitiveness—trade and firm—are of particular interest. Trade competitiveness is narrowly defined as the ability of U.S. producers to export and to compete with imports in domestic markets. Firm competitiveness refers to the ability of U.S.-based firms to compete at home and abroad. In both cases, a crucial element of competitiveness is producers' ability to increase earnings while meeting the competition in international markets.²⁸

These two types of competitiveness are strongly related. The "product cycle" hypothesis suggests that the technological innovations that later lead to foreign direct investment and overseas production are initially produced and sold domestically, and then exported.²⁹ Firm competitiveness is thus initially exhibited through trading performance (described here as trade competitiveness). Less directly, the ability to capture domestic and export markets in the early stages of an innovation's life—trade competitiveness—may be a necessary condition for the innovative effort which enhances a firm's overall competitive position.

As measures of the strength of the Nation's science and technology system, the two aspects of competitiveness must be treated separately. Trade competitiveness results not just from superior technology, but also from those factors that determine the market price for goods of a given quality. In particular, trade competitiveness is largely a function of the exchange rates between the dollar and the currencies of the other major trading countries. Firm competitiveness, on the other hand, is less directly related to the Nation's economic health, but has stronger ties to technological prowess. (Other factors,

such as brand-name advantages, labor and marketing skills, and managerial excellence, are also relevant.)

In assessing the competitive strengths and weaknesses of U.S. commercial science and technology, changes in the overall competitiveness (broadly defined) of U.S. technology must be distinguished from shifts in the channels (discussed above) used to exploit technological advantages internationally. Data on each of the three channels are therefore examined, both in terms of the different aspects of competitiveness, and as evidence of the overall strength of the U.S. commercial S/T system.

High-Technology Trade Competitiveness

The combination of slower growth in U.S. exports of high-technology products and the steady increase of imports has led to a dramatic decline in the U.S. high-technology trade surplus. Specifically, trade dropped from about \$31 billion in 1981 (1982 prices) to \$3 billion in 1985, and a deficit of \$2.6 billion in 1986. (See figure O-26 in Overview.) This stark picture has led to widespread concern about a loss of U.S. competitiveness in these leading industries.

There has been a larger loss in U.S. trade competitiveness in all manufactured products, besides that in the high-technology product groups. Whether this implies a loss of U.S. technological leadership depends in part on whether the product groups described as "high-technology" are in fact those closest to the leading edges of technology. Since these high-technology product groups are defined at the three-digit standard industrial classification (SIC) level, each group contains products of varying levels of technological sophistication. A loss in U.S. market share in a product group may in fact be an increase in the volume of the less sophisticated goods in the product group, which might be produced primarily in other countries. It may also reflect overseas production of goods that had once been near the leading edge of technology, but that are now standardized and can be produced offshore. At the same time, a U.S. technological lead might exist or be developing in products that lie outside those defined as high-technology.

In the rapidly changing commercial world, all three of these explanations apply at various times. The first can be described as a loss of U.S. trade competitiveness, without implying a loss of U.S. technological leadership; the second is a consequence of the evolution of products and technology. The third entails unobserved strength in U.S. commercial science and technology.

If the U.S. is indeed losing its technological leadership, there should be a shift in market share from the United States to its nearest technological competitors—i.e., the other advanced industrialized countries of the Organisation for Economic Co-operation and Development (OECD). A loss of market share in individual high-technology products might reflect increased age and standardization of the technologies used or included in those products, thus permitting more countries to compete effectively. Loss of market share in this case need not reflect movement of U.S. firms away from the technological frontier, but instead, broader participation in technology.

²⁷See Teece (1986a), pp. 285-305.

²⁸For a related definition which differentiates between "corporate competitiveness" and "national competitiveness," see Cohen, Teece, Tyson, and Zysman (1984), p. 2.

²⁹See Vernon (1966) and Hufbauer (1966).

If, however, the weaker U.S. trade performance in high-technology products does reflect a weaker ability to perform at the technological frontier, then loss of competitiveness would be most severe in those product groups that most intensively perform and use applied research and development. By combining analysis of national market shares in high-technology products and U.S. performance with regard to a smaller subset of these products, the issue of technological leadership can be disentangled somewhat from the more general issue of the loss of U.S. trade competitiveness.

Since 1965, the United States has accounted for between 23 and 30 percent of world exports of high-technology products.¹⁰ In 1984, the latest year for which data are available, the United States was still the world's largest exporter of high-technology products. Although the U.S. share of the world market for high-technology goods declined from around 30 percent in the late 1960's to about 25 percent in the late 1970's, the U.S. share has more recently hovered around 27 percent. (See appendix table 7-10.) Furthermore, exports of high-technology products have tended to increase for all of the largest industrialized economies, although there was a downturn for all countries in the early 1980's, coincident with economic recessions for the United States and most of its trading partners.¹¹ (See figure 7-8.)

Thus, in spite of the relatively difficult competitive situation that has faced U.S. producers in recent years,

U.S. exporters have been relatively successful at defending—and in some cases increasing—their market shares, at least in relation to their competitors in the other major industrialized countries.

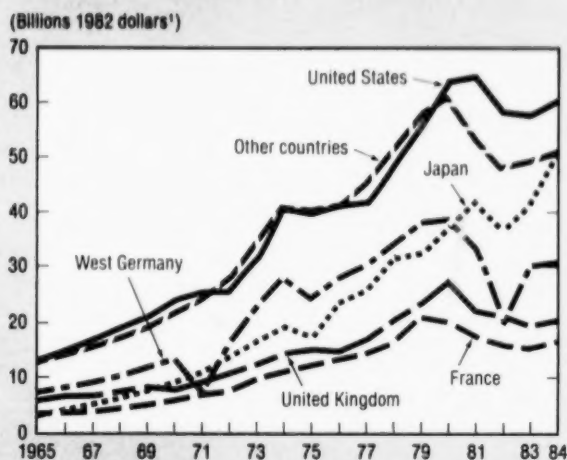
The market shares discussed here include the bulk of the world's trade of high-technology products. However, these data omit those "newly industrialized countries" (NIC's)—e.g., Taiwan, Singapore, South Korea, Brazil, and Mexico—that are increasingly active in this area. For example, U.S. imports from the East Asian NIC's increased by more than 115 percent in real terms between 1980 and 1986, during a period when total U.S. imports of high-technology products from all countries grew by about 100 percent. In 1986, the East Asian NIC's accounted for about 18 percent of U.S. imports of these products, making these countries key participants in at least the U.S. high-technology markets.¹² (See appendix table 7-11.)

In the earlier discussion of trade in high-technology products as a channel for the international diffusion of technology, three high-technology product groups—aircraft and parts, communications equipment and electronic components, and office and computing machines—were identified as being both intensively exported and intensive in their performance and use of applied research and development. U.S. exporters have had mixed success in defending their market shares in these three product groups. While the U.S. share of the high-technology product markets as a whole was about the same in 1984 as in 1975, it increased in the communications equipment and electronic components and office and computing machines groups, but fell sharply in the aircraft and parts group. (See figure 7-9.) The latter decline probably largely reflects competition from the Western European Airbus commercial transports, while the other two product groups demonstrate U.S. strength in computers and microelectronics.

It is in these two groups, and in high-technology products as a whole, that the Japanese challenge is manifested. Japan maintains the largest market share in communications equipment and electronic components (which includes radio and television equipment, as well as more sophisticated electronic circuitry). It also increased its share of office machines and computers exports from 11 percent in 1975, less than either West Germany or the United Kingdom, to almost 18 percent in 1982; this made Japan the second-leading computer exporter in the world.

These data provide little evidence of a generalized loss of U.S. technological leadership to any particular country. Instead, the loss of U.S. trade competitiveness in individual areas is caused by the appearance of strong rivals—Western Europe in the aircraft industry and Japan in electronics. There has also been a shift of markets from the U.S. to producers from the NIC's, presumably because an aging technological base opens a competitive advantage for low-cost operations. However, nowhere is there a clear loss of U.S. technological leadership; rather,

Figure 7-8.
Exports of high-technology products,
by selected countries



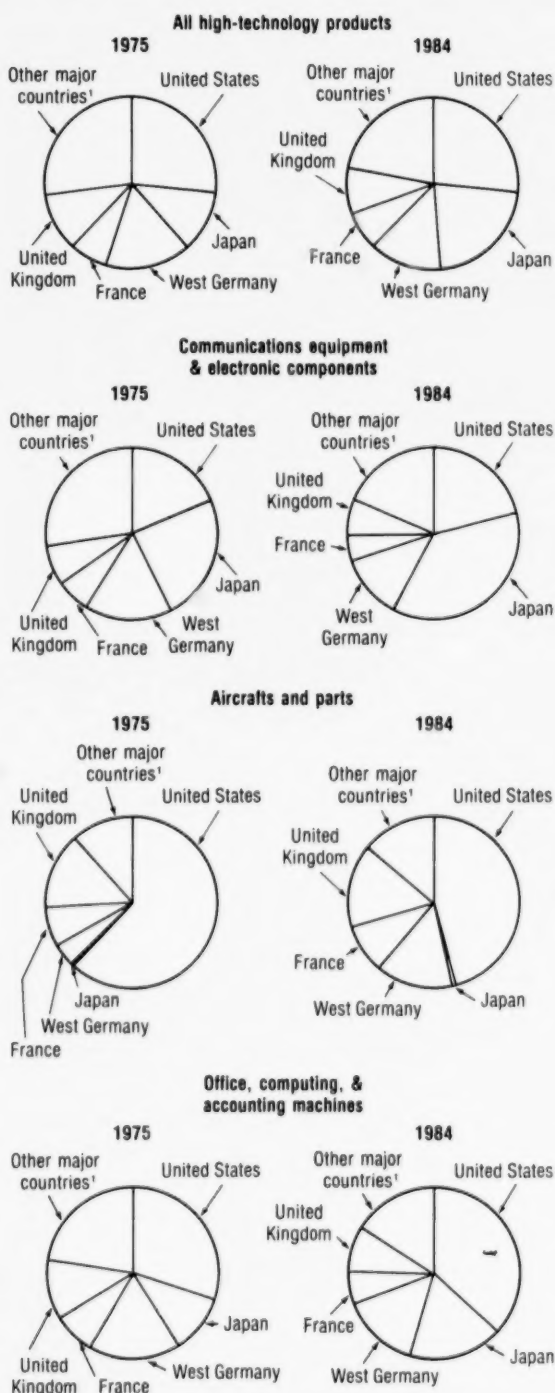
¹GNP implicit price deflators used to convert current to constant dollars.

See appendix table 7-10.

Science & Engineering Indicators — 1987

¹²See U.S. Department of Commerce (1986b); and Finan, Quick, and Sandberg (1986).

Figure 7-9.
Export market shares, selected high-technology products



¹Austria, Belgium/Luxemburg, Canada, Denmark, Italy, Netherlands, Norway, Sweden and Switzerland

See appendix table 7-12

Science & Engineering Indicators — 1987

it appears that the competition is catching up. Moreover, the race for new technologies is being run faster than ever before.

Direct Investment and Firm Competitiveness

Ideally, to analyze firm competitiveness, the profitability of U.S. firms engaged in international direct investment would be examined in conjunction with investment levels or total sales by overseas subsidiaries. In the absence of data on the profitability of direct investment, however, such analysis is limited to comparing levels of activity related to direct investment. Assuming that, overall, such activity meets minimum profitability criteria (otherwise it would not be undertaken), comparisons of direct investments undertaken by nationals of different countries can help to identify investment changes resulting from firms' competitive positions rather than from broader changes in the international environment.

The U.S. direct investment position abroad in manufacturing industries grew steadily until the mid-1970's, and has declined in real terms since 1980. (See figure 7-1.) A similar pattern is apparent for the United States with regard to direct investment overseas in all industries:¹¹ in 1984, the U.S. position had fallen by \$30 billion (at 1982 prices) since 1981. During the same period, however, the direct investment positions of most of the other major investing countries had increased substantially, so that direct investment throughout the world had increased at an average rate of about 3.4 percent per year (after inflation) since 1973. (See figure 7-10 and appendix table 7-13.) The increase in holdings is broadly based; moreover, of the countries for which data are separately available, only firms based in Switzerland have decreased their holdings.

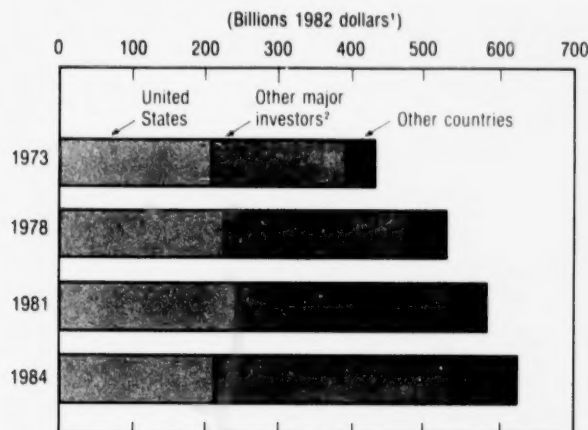
The stock of international direct investment held by developed countries other than the United States increased by about \$75 billion between 1980 and 1984. During the same period, foreign direct investments in the U.S. from other developed countries increased by about \$70 billion. As the growth in direct investment holdings by firms based outside the United States has taken place almost entirely within the United States, it is possible that U.S. firms are suffering from a climate unfavorable to international direct investment. There also may be conditions that are particularly unfavorable to U.S.-based direct investment, or there may be slippage in the technological competitiveness of U.S. firms. While nontechnological conditions for international direct investment cannot be delineated here, the importance of foreign markets to U.S. firms suggests the relevance of the question to U.S. science and engineering policy.

Does the weakening of the U.S. position in international direct investment indicate a weakening of our technological competitiveness, or simply a shrinkage of the channels for international marketing of innovations? To determine this, it is useful to examine the direct invest-

¹¹Data on the position in manufacturing are not available for countries other than the United States.

Figure 7-10.

**Value of international direct investment holdings,
by ownership of investments**



¹GNP implicit price deflators used to convert current to constant dollars.

²"Other major investors" includes, United Kingdom, West Germany, Japan, Switzerland, the Netherlands, Canada, and France.

See appendix table 7-13.

Science & Engineering Indicators — 1987

ment experiences of some of the United States' most significant technological competitors.

The share of all international direct investment holdings owned by U.S. residents fell from 48 percent in 1973 to 34 percent in 1984; most of this reduction occurred between 1981 and 1984. (See figure 7-11.) The U.K. share was more or less constant, while residents of West Germany increased their share of all holdings from 6 to 9 percent. Japanese holdings grew from 5 to 8 percent, and the shares accounted for by smaller investors rose from 10 to 14 percent.

To some extent, the sharp decline in the U.S. position since 1981 reflects changes in the dollar value of U.S. holdings overseas. Such holdings generally fall when exchange rates climb, as they did during the period in question. However, the decline in the U.S. share dates from before the recent period of a very strong dollar, suggesting that other factors besides exchange rates were present.

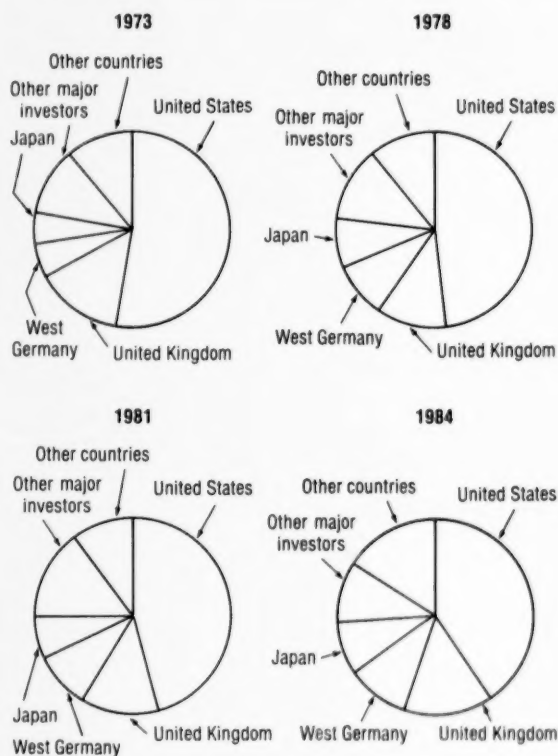
In particular, since about one-half of the reduced U.S. share was taken up by the two countries—Japan and West Germany—that are widely assumed to be the

strongest technological competitors to the United States, there is reason to conclude that reduced firm competitiveness has contributed to the reduced U.S. presence.

If direct investment positions somewhat reflect the technological positions of a country's firms in the international marketplace, then the substantial growth in direct investment coming from the "other countries" (i.e., those outside the industrialized countries of the OECD) may indicate a broadbased diffusion of technological prowess. This diffusion foreshadows heightened competition in all markets in which U.S. firms operate.

Figure 7-11.

**International direct investment, distribution
of ownership**



See appendix table 7-13.

Science & Engineering Indicators — 1987

REFERENCES

- Boretzky, M., "The Threat to U.S. High Technology Industries: Economic and National Security Implications," unpublished report, U.S. Department of Commerce, International Trade Administration, March 1982.
- Caves, R.E., *Multinational Enterprise and Economic Analysis* (Cambridge, England: Cambridge University Press, 1982).
- Cohen, S., D.J. Teece, L. Tyson, and J. Zysman, "Competitiveness," *Global Competition—The New Reality, Volume III* (Washington, DC: The President's Commission on Industrial Competitiveness, 1984).
- Council of Economic Advisers, *Economic Report of the President* (Washington, DC: Government Printing Office, 1985).
- Davis, L.A., "Technology Intensity of U.S. Output and Trade," International Trade Administration staff report (Washington, DC: U.S. Department of Commerce, February 1982).
- Finan, W.F., P.D. Quick, and K.M. Sandberg, "The U.S. Trade Position in High Technology: 1980-1986," report prepared for the Joint Economic Committee of the U.S. Congress, October 1986.
- Hilke, J.C. and P.B. Nelson, *International Competitiveness and the Trade Deficit*, Bureau of Economics Staff Report to the Federal Trade Commission (Washington, DC: Federal Trade Commission, May 1987).
- Horst, T., "The Theory of the Multinational Firm: Optimal Behavior under Different Tariff and Tax Rules," *Journal of Political Economy*, Vol. 79, September/October 1971.
- Hufbauer, G.C., *Synthetic Materials and the Theory of International Trade* (London: G. Duckworth and Company, 1966).
- Kelly, R.K., "Alternative Measures of Technology-Intensive Trade," *Staff Economic Report* (Washington, DC: U.S. Department of Commerce, Office of Economic Research, 1976).
- Mansfield, E., A. Romeo, and S. Wagner, "Foreign Trade and U.S. Research and Development," *Review of Economics and Statistics*, Vol. LXI, February 1979.
- National Academy of Sciences, *Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition* (Washington, DC: National Academy Press, 1987).
- Shea, M., "U.S. Business Enterprises Acquired or Established by Foreign Direct Investors in 1985," *Survey of Current Business*, Vol. 66, No. 5, May 1986.
- Teece, D.J., "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy," *Research Policy*, Vol. 15, No. 6, December 1986a.
- Teece, D.J., "Technology Transfer by Multinational Firms: The Resource Cost of International Technology Transfer," *Economic Journal*, June 1977.
- Teece, D.J., "Transaction Cost Economics and the Multinational Enterprise, An Assessment," *Journal of Economic Behavior and Organization*, Vol. 7, 1986b.
- U.S. Department of Commerce, Bureau of Economic Analysis, "Foreign Direct Investment in the United States: Detail for Position and Balance of Payments Flows, 1986," *Survey of Current Business*, Vol. 67, No. 8, August 1987a.
- U.S. Department of Commerce, Bureau of Economic Analysis, *U.S. Direct Investment Abroad: 1982 Benchmark Survey Data* (Washington, DC: Government Printing Office, 1985a).
- U.S. Department of Commerce, Bureau of Economic Analysis, "U.S. Direct Investment Abroad: Country and Industry Detail for Position and Balance of Payment Flows, 1984," *Survey of Current Business*, Vol. 65, No. 8, August 1985b.
- U.S. Department of Commerce, Bureau of Economic Analysis, "U.S. Direct Investment Abroad: Country and Industry Detail for Position and Balance of Payments Flows, 1986," *Survey of Current Business*, Vol. 67, No. 8, August 1987b.
- U.S. Department of Commerce, Bureau of Economic Analysis, "U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and Their Foreign Affiliates, Preliminary 1984 Estimates," mimeograph, October 1986a.
- U.S. Department of Commerce, Bureau of Economic Analysis, "U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and Their Foreign Affiliates, Preliminary 1985 Estimates," mimeograph, June 1987b.
- U.S. Department of Commerce, International Trade Administration, *International Direct Investment: Global Trends and the U.S. Role* (Washington, DC: Government Printing Office, August 1984).
- U.S. Department of Commerce, International Trade Administration, *United States Trade Performance in 1985 and Outlook* (Washington, DC: Government Printing Office, 1986b).
- U.S. Department of Commerce, International Trade Administration, *An Assessment of U.S. Competitiveness in High Technology Industries* (Washington, DC: Government Printing Office, 1983).
- Vernon, R., "International Investment and International Trade in the Product Cycle," *Quarterly Journal of Economics*, Vol. 80, May 1966.

Chapter 8

Public Attitudes Toward Science and Technology

Public Attitudes Toward Science and Technology

HIGHLIGHTS

- *A survey of the adult public in 1985 found that 21 percent are "attentive" to science and technology (S/T), as defined by their knowledge, interest, and information consumption. This is about twice as many as in the late 1950's. Higher levels of education are the most distinguishing feature of attentive people. In nearly every case, their attitudes toward science and technology are more favorable than the attitudes of others. (See p. 142.)*
- *In spite of these levels of attentiveness, few Americans have much understanding of science and technology, as revealed by their understanding of technical terms and their ability to explain how a familiar technology—the telephone—works. (See p. 143.)*
- *Americans are dissatisfied with the teaching of science and mathematics in their schools, and wish to see it improved. On the other hand, Japanese adults in a 1987 survey expressed a fair level of satisfaction with their science and mathematics education, but doubted that Japanese education is nurturing the individualism and creativity that scientists need. (See pp. 143-145.)*
- *The public overwhelmingly believes that science and technology have brought more benefits than harmful results. However, the number who consider the harmful results greater has increased gradually since 1979. The areas in which science and technology are seen to be most beneficial are mainly medical, technical, and economic. Far fewer persons believe that science and technology have benefited world peace or moral values. The Japanese agree about the relative benefits of science and technology in some of these areas, but on the whole their assessment is more negative. (See pp. 147-148.)*
- *The public expects significant outcomes from science and technology in the next 25 years or so. On the positive side, about one-half think it is very likely that cures will be found for cancer and AIDS. There is little expectation of an accidental release of a genetically engineered microbe. On the negative side, more than 40 percent believe there will be another nuclear plant accident like that at Three Mile Island and an accidental release of a toxic chemical that will kill many people. The Japanese public's expectation of positive results is very similar to that of the American public. (See pp. 148-150.)*
- *Americans are optimistic about the effect of science and technology on their jobs. The Japanese and, especially, the Americans agree that science and technology have improved general working conditions. While most Americans also agree that science and technology will make work more interesting in the future, the Japanese are almost evenly split on this. (See p. 150.)*
- *Americans are optimistic about the effects of automation and the need for it. The Americans and Japanese largely agree that automation leads to a loss of some jobs. By a small margin, however, Americans believe that the net effect of computers and automation is to increase employment. The Japanese disagree strongly. The Japanese and—especially—the American publics believe that factory automation is necessary to meet foreign competition. (See pp. 150-152.)*
- *Scientists generally are highly regarded by the public. For many years, they have ranked second only to doctors on a list of professionals in whom the American public has confidence. The American, Japanese, and French publics agree that scientists work for the good of humanity. On the other hand, the Americans and the French—but not the Japanese—agree that scientists have a power that makes them dangerous. (See pp. 152-153.)*
- *Americans hold many ideas that are outside the scientific mainstream. Large minorities (between 40 and 50 percent) believe in lucky numbers and unidentified flying objects (UFO's), and that rocket launches have affected the weather. Similar numbers doubt that humans evolved from other animal species. People attentive to science and technology accept UFO's more often than others do. About one-quarter of Americans with graduate degrees believe space activities have affected the weather, believe in lucky numbers, and do not believe in evolution. Japanese attitudes are similar on many of these questions, except for the wider acceptance of evolution by the Japanese. (See pp. 153-155.)*
- *About 8 percent of the American public say they act on the basis of their astrological forecasts. Support for astrology is strongest among women, the youngest and oldest age groups, and those with the least education. These groups are generally the ones most likely to take views opposed in some way to science and technology. (See pp. 155-156.)*
- *Americans believe their country is leading the rest of the world, except for Japan, in science and technology. In basic science, they believe the United States is ahead of West Germany, Britain, France, and (less clearly) the Soviet Union. By a narrow margin, the United States is considered ahead of Japan. With respect to military technology, the United States is considered to lead all these countries, but by a relatively narrow margin in the case of the Soviet Union. However, in civilian or industrial technology Americans believe Japan is definitely ahead, while the United States leads the other countries. (See pp. 157-158.)*

- *The Japanese believe the United States leads in all areas, but place themselves ahead of the other four countries. In basic science and technology and—to a lesser degree—in technology related to everyday living, they consider the United States to be clearly ahead of them. In industrial technology, they consider the United States to be ahead, but by a very small margin. (See p. 158.)*
- *The public believes that science and technology are long-range investments. About 80 percent believe that the government should support scientific research even when it brings no immediate benefits. (See p. 158.)*
- *The public is willing to allow research to go forward in many areas of interest to nonscientists. This includes medical research involving animals. Support is weaker for research that might lead to new life forms, and there is clear opposition to research designed to lead to new biological or chemical weapons. In those areas where comparison is possible, the Japanese are much more reluctant about allowing research to be pursued. (See pp. 158-160.)*
- *Americans are generally satisfied with the level of government regulation regarding food additives, atomic power plant construction, pharmaceutical manufacture, genetic engineering research, and basic research. Except for basic research, the Japanese wish to see more regulation of all of these, especially food additives. (See pp. 160-161.)*
- *In terms of benefits and costs (or risks), the public narrowly is in favor of the space program, genetic engineering, and nuclear power. About one-half the public favors each one, but there are corresponding minorities of 40-45 percent in opposition. People attentive to science and technology support the space program and genetic engineering research more than the broad public does. In the case of nuclear power, however, "attentives" are about evenly split for and against. (See pp. 161-162.)*
- *The Space Shuttle Challenger accident did not diminish public support for the space shuttle program. In February 1986, immediately after the accident, only a minority thought the explosion was a major setback for the shuttle program. One-half were willing to increase Federal funding for the program if that were needed to get it back on schedule. Nearly everyone believed that manned flights would be resumed and that the shuttle is still an outstanding example of American technology. In June 1986, after the Rogers Commission report, there was more acknowledgment of a major setback and of major design flaws in the shuttle. Support for the program remained high, however. (See pp. 162-163.)*
- *The accident at the Soviet nuclear power plant at Chernobyl provoked general concerns about nuclear power. In June 1986, about a month after the accident, Americans blamed the accident on design errors and operator/manager errors. More than 90 percent stated that there are still major unanswered questions about the safety of nuclear power plants in all countries, and a small majority thought that the risk involved in generating nuclear power should block the construction of new nuclear plants. Still, a small majority believed that the world will primarily depend on nuclear sources of energy 50 years from now, and a large majority believed that science and technology will provide a long-term solution to the energy problem. (See pp. 164-165.)*
- *The Challenger and Chernobyl accidents did not erode general confidence in science and technology. Immediately after the Space Shuttle Challenger accident, public support for the space program increased. Most measures of general public support for science and technology went up. By June 1986, support was still higher than before the accident. The Chernobyl accident did not noticeably affect the public's perception of the risk/benefit balance of nuclear power. (See pp. 163-165.)*

Science and technology deeply affect the public through such developments as personal computers, nuclear power, and the space shuttle program. Policymakers must know both if the public understands and accepts these developments, and exactly what the public knows and believes about science and technology in general. This chapter continues and updates earlier *Science Indicators* explorations of such questions. It also introduces some subjects not treated before, such as public acceptance of scientific conclusions, the public's view of the limits of science, and the effect of major technological accidents on attitudes toward science and technology.

Most of this material is taken from a national survey of adults performed for this report in November and De-

cember 1985.¹ Supplementary surveys were done in January-February 1986 and June-July 1986, mainly to measure the effects on the public of the technological accidents involving the Challenger Space Shuttle and the Chernobyl nuclear reactor.

For the first time, this chapter also presents an extensive amount of data from surveys performed in other

¹In November and December, 1985, a national sample of 2,005 adults was interviewed by telephone from the Public Opinion Laboratory at Northern Illinois University. This was 80.2 percent of the original sample of 2,500. With a sample of this size, results are uncertain by ± 3 percent or less, at the 95-percent confidence level. With subsamples, the uncertainty will be greater. For more information, see Miller (1988).

countries. In particular, a major survey was performed in Japan in March 1987 using many of the questions in the 1985 U.S. survey.² Data from this study provide an unparalleled opportunity to compare public attitudes in the two countries on many important aspects of science and technology policy. At the same time, it should be recognized that the comparison of survey data obtained in widely different cultures using quite different languages presents problems of method that have only begun to be addressed. Hence the conclusions drawn in this chapter about attitudes in different countries should only be taken as the best information available at the present time.

KNOWLEDGE, INTEREST, AND ATTENTIVENESS REGARDING SCIENCE AND TECHNOLOGY

The public's ability to participate effectively in science- and technology-related public issues depends on having a certain level of relevant knowledge and interest. Efforts have been made to measure and report on such knowledge and interest regarding both particular issues and science and technology in general.

Attentiveness to Science and Technology

In this chapter (as in previous *Science Indicators* reports), distinctions are made among that portion of the public "attentive" to science and technology, an "interested" or "potentially attentive" group, and the remainder of the public. These three groups were identified by asking all respondents a set of questions about their knowledge of science and technology, their interest in science and technology, and their habits of information acquisition. Those who scored high on all three measures were considered to be *attentive*.³ These are the members of the public most likely to get involved when an issue related to science and technology becomes a public controversy. These persons may, for example, contact legislators or opinion leaders or write letters to newspaper and magazine editors. The attitudes of this group of citizens are of special importance not only because of their likely participation, but also because they have pre-

sumably thought more about the science- and technology-related issue than have other citizens, and therefore are more likely to express stable attitudes in which they have confidence when asked questions about science and technology.

A second group of respondents is defined as *interested* rather than *attentive* because it meets the interest condition but not the knowledge and information acquisition conditions for being recognized as *attentive*. Members of this group are considered potentially *attentive* because they presumably would be willing to acquire information and become *attentive* under certain conditions.⁴ This is thus an especially suitable group to which to address science and technology information programs.

The third group, *the remaining public*, is the group most likely to report opinions that are easily changed and that these respondents themselves do not consider well grounded. However, this group's views about science and technology are also important—not only because this group is so large, but also because under special circumstances its members too may be stirred into action by some situation that affects them directly.

Science and technology is only one of the many fields to which an intelligent and busy person can pay attention. This model therefore does not imply that everyone ought to be attentive to science and technology, that there is something wrong with not being attentive, or that the professional community should address itself to only one group. Rather, this way of dividing the public identifies three groups with different information needs; groups whose expressed attitudes are often different. In this chapter, the responses of all three groups frequently will be presented so that their attitudes can be compared.

About 20 percent of the U.S. adult public qualifies as attentive to science and technology. (See table 8-1.) While the level of attentiveness has fluctuated around this figure since 1979, it was only one-half this high in 1957. This suggests a continuing growth in the public's awareness of science and technology. College students, who were separately surveyed, also showed high levels of attentiveness; in 1983, 25 percent were attentive. In 1985, both the college students and the broader adult group showed unexplained drops in attentiveness from their 1983 levels.⁵

Citizens attentive to science and technology are found in all demographic groups. There is no significant difference in the attentiveness of different age groups. Men, however, are more likely to be attentive than are women. (See appendix table 8-1.) The most significant predictor of attentiveness to science and technology is education. Science and technology appear to require higher levels of education for people to feel comfortable and informed about them. College students in 1985 showed slightly lower levels of attentiveness and interest than the corresponding portion of the adult public, those with only a high school education.

²The survey was sponsored by the Public Relations Office of the Prime Minister's Secretariat. Personal interviewing was done in March 1987 with 2,334 respondents out of an original sample of 3,000, for a response rate of 77.8 percent. For a complete report of this survey, see Office of the Prime Minister of Japan, Public Relations Office (1988). This report is being issued simultaneously with *Science & Engineering Indicators—1987*, and is the source for all Japanese data discussed in this chapter.

³Specifically, respondents were regarded as attentive if they reported being very interested and very well-informed about either new scientific discoveries or the use of new inventions and technologies. In addition, respondents had to have a pattern of sustained information acquisition through the regular use of two or more news sources. Such people are considered most likely to keep up with science- and technology-related issues. In measuring attentiveness, the respondents' self-reported knowledge was used instead of testing their actual knowledge. Since attentiveness serves as an indicator of willingness to become involved politically, self-perceived knowledge is more important for this purpose than actual knowledge. See Miller (1983a).

⁴For more information on this model, see Miller (1983a).

⁵For a study of college student attitudes toward science and technology and other subjects in 1985, see Miller (1986).

Table 8-1. Percent of American public attentive¹ to and interested in science and technology

	Adults					College students	
	1957	1979	1981	1983	1985	1983	1985
Attentive	10	19	20	24	21	25	16
Interested	12	21	19	28	26	22	23
N =	1,919	1,635	3,195	1,630	2,005	2,011	2,373

¹ Interested in and informed about science and technology, and regularly acquiring information.

Note: N in each case is the number of respondents.

See appendix table 8-1. See also Miller (1986).

Science & Engineering Indicators—1987

Knowledge of Scientific and Technical Terms

Part of the public's scientific and technological sophistication is its ability to recognize and understand certain S/T terms. Respondents were given a list of five science- and technology-related terms that someone might encounter through newspapers, magazines, or television, and were asked if they had a "clear understanding," a "general sense," or "little understanding" of these terms. (See table 8-2.) The terms chosen were relatively familiar ones and together covered a broad range of fields. Almost 30 percent reported that they had a clear understanding of what "radiation" is and what a "molecule" is. Most respondents reported little understanding of "DNA" or "GNP" and one-half had little understanding of "computer software." The highest levels reporting a clear understanding of these items were among attentives² and, correspondingly, among males and those with higher levels of education.

Another dimension of scientific knowledge is having some conception of how science and technology work. Respondents thus were asked what it means to study something scientifically. (See table 8-2.) This is a point that may come up when commercial advertising suggests that some product has been tested scientifically, or when results are published from a new study of the effect of diet on susceptibility to a disease. Even among the attentive public, only a minority report a clear understanding of what scientific study is. About one-half report that they have a general sense of what it is.³

There was no similar question by which to gauge general comprehension of technology. Instead a very common technology—the telephone—was selected, and respondents were asked whether they understood its operation. Only 1 in 12 Americans claims to have a clear understanding of how a telephone works. (See table 8-2.) About one-half of the public claims a general sense of how telephones work, while one-third claims little understanding. Appendix table 8-2 shows the response of different demographic groups.

To determine the accuracy of this self-reported level of understanding, respondents were sometimes asked to state in their own words what they understood by a particular item.⁴ There were far fewer who actually understood the items than had previously claimed a clear understanding of them. (See table 8-3.) Attentives did better than others, but still did not show high levels of understanding. Demographic differences are shown in appendix table 8-3. Correct responses are strongly related to higher levels of education. While only a small minority answered it correctly, the question about telephones brings out the strongest difference between the sexes and among age groups;⁵ the question about scientific study shows no differences with respect to sex.

The Japanese survey also asked whether respondents understood certain terms, but did not attempt to test the reported understanding. Three of the terms—GNP, computer software, and DNA—were the same as those used in the U.S. survey. While absolute numbers in the two surveys cannot be compared on this question, it is noteworthy that the Japanese responses on these three terms fell in the same order as did the American responses, with GNP being most familiar to both Japanese and American respondents and DNA least familiar. (See table 8-2 and appendix table 8-4.)

Attitudes Toward Science and Engineering Education

The public expresses widespread dissatisfaction regarding the teaching of science and mathematics in American schools. (See table 8-4.) Correspondingly, there is a wish to see science, and especially mathematics, taught in every year of high school.⁶

The American question was worded in negative terms ("The quality of science and mathematics education in American schools is inadequate") and evoked a high level of negative sentiment about American education. Japanese respondents were asked a slightly different ques-

²It should be noted that these items are part of the knowledge condition that enters into the definition of attentiveness.

³Miller (1988).

⁴The question was not asked of those who had said they had little understanding of the item.

⁵Here and elsewhere in this chapter, varying responses among age groups seem to be due to differences in education. Age as such does not seem to explain much of the response. See Miller (1988).

⁶See also chapter 1, "Precollege Science and Mathematics Education."

Table 8-2. Reported understanding of various aspects of science and technology, by attentiveness: 1985

Aspect	Total public	Attentive public	Interested public	Remaining public
Percent claiming clear understanding				
Radiation	29	45	31	21
Molecule	27	45	33	18
GNP	23	41	24	16
Computer software	20	34	20	15
DNA	14	24	16	9
Scientific study	29	42	31	24
How a telephone works	18	24	20	14
N =	2,005	417	517	1,071

"Radiation: When you read or hear the term 'radiation'; do you have a clear understanding of what it means, a general sense of what it means or little understanding of what it means?"

See appendix table 8-2.

Science & Engineering Indicators—1987

Table 8-3. Actual understanding of various aspects of science and technology, by attentiveness: 1985

Aspect	Total public	Attentive public	Interested public	Remaining public
Percent responding correctly ¹				
Molecule	10	15	10	7
Scientific study	13	16	12	12
How a telephone works	8	13	7	6
N =	2,005	417	517	1,071

"In your own words, could you tell me what a molecule is?"

¹ Question was asked only of those who previously had stated they had either a "clear understanding" or a "general sense" of this aspect. Percentages are based on total sample. Responses were coded at the Public Opinion Laboratory, with tests of intercoder reliability.

See appendix table 8-3.

Science & Engineering Indicators—1987

Table 8-4. Attitudes toward science and mathematics education in the United States: 1985

	Agree	Disagree	No opinion
Percent			
The quality of science and mathematics education in American schools is inadequate	63	29	8
Every high school student in the United States should be required to take a science course every year	69	28	3
Every high school student in the United States should be required to take a math course every year	87	12	1

SOURCE: Jon D. Miller (1988)

Science & Engineering Indicators—1987

tion: whether the science and mathematics coursework in their schools is serving the purpose of nurturing the students' awareness of science. Forty-six percent of the Japanese surveyed agreed, 35 percent disagreed, and 20 percent had no opinion.

Many writers have suggested that Japan will not be able to sustain its technological growth if it cannot create its own basic scientific and technological knowledge—knowledge that previously could be borrowed from other countries. This will require a creativity and en-

Table 8-5. Reported use of public information sources: 1985

Source and frequency (times per year)	Total public	Attentive public	Interested public	Remaining public
	Percent			
Watches science television:				
Never	29	16	25	37
Occasionally	51	54	54	49
Regularly	20	31	21	15
Visits a public library:				
None	33	22	29	39
One or two	16	17	18	14
Three or more	51	61	53	47
Visits a zoo or aquarium:				
None	52	44	53	54
One or two	37	42	37	36
Three or more	11	14	10	10
Visits a science and technology or natural history museum:				
None	62	47	62	68
One or two	27	35	27	24
Three or more	11	18	11	8
Visits an art museum:				
None	69	56	68	74
One or two	23	31	24	20
Three or more	8	13	9	6
Reads science magazines:				
Never	84	68	84	90
Occasionally	6	7	9	4
Regularly	10	26	7	6
N =	2,005	417	517	1,071

SOURCE: Jon D. Miller (1988)

See appendix table 8-5.

Science & Engineering Indicators—1987

trepreneurship that some allege does not exist in Japan. Japanese respondents thus were also asked if "Compared with other countries, Japan is very meager in training individualists and creative scientists." This question too was negatively worded, and it found 53 percent of respondents agreeing (12 percent "completely agreed"), 27 percent disagreeing, and 19 percent uncertain. Agreement was highest among respondents with university and college degrees.

PERSONAL ACTIVITIES INVOLVING SCIENCE AND TECHNOLOGY

In spite of the limitations in the public's knowledge, there still are various way in which many people deal with science and technology on a daily basis in their home life, their work, and even in their leisure-time activities. Data are available for some of these activities, and they help to show the extent to which various groups within the public take advantage of the opportunity to learn about or use science and technology.

Consumption of Information

Adult Americans report a moderately high level of exposure to publicly available sources of science and technology information. (See table 8-5.) All of the activities listed for these sources are primarily leisure-time activities, and can be arranged roughly in order of difficulty. Thus, reading science magazines is the activity with the fewest participants,¹¹ since special effort must be made to acquire the magazines, and some level of sophistication is required to read them. Most people, on the other hand, can watch and enjoy an occasional National Geographic Special very easily; therefore, there is a low percentage of the public that does not watch science-

¹¹The questions on science magazines and science television are not strictly comparable with the others, since the list of responses is different. However, the numbers who never read science magazines or watch science television can be compared with the numbers who do the other activities 0 times per year.

related television at all. In between are visits to zoos, aquariums, and museums. Some effort is required to do these things, but—especially in the case of zoos and aquariums—there is little that is difficult to understand.

To help interpret the frequency of use for these information sources, the frequency of use for two nonscientific or general information sources—art museums and public libraries—is also shown. Art museums are slightly less popular than science and technology museums. Public libraries, on the other hand, have the highest number of users who visit three or more times per year. Next to television, libraries are the most widely accessible of the sources listed; they also provide the broadest range of scientific and other information.

Predictably, attentives take part in these information acquisition activities more than do other members of the public.¹² Substantial differences between the attentive public and the remaining public also exist for watching science television and visiting science and technology museums. Attentives are also heavier users of public libraries and art museums. This suggests that attentives are heavier users of information and culture sources in general, apparently because of their higher level of education.

If one looks at demographic characteristics, these patterns of use of information sources are more understandable. (See appendix table 8-5.) Attendance at museums, zoos, and aquariums seems to decrease sharply with increasing age; clearly, these are avenues more suitable for imparting information to younger adults. Since many adults visit such places mainly to bring their young children, this may help to explain the lower attendance by older adults. Magazine use decreases at both ends of the age spectrum, while use of science-related television increases with age. Education is a strong influence on the level of use of any type of information source. Since the average educational level is lower for the youngest and the oldest Americans, education may help to explain these differences in participation by age.

Another major source of information is newspapers. There has been considerable expansion in the number of weekly science sections appearing in American newspapers, particularly from 1984 to 1986. (See figure 8-1.) While many of these sections are exclusively devoted to health and fitness, there also has been a considerable growth in science sections presenting a broader range of materials. This implies a growing public interest in scientific subjects of all kinds and an increasing public consumption of such information, in part because more and more consumer goods are products of science and technology. This interest is further evidenced by the fact that there were about 81 daily newspapers with a science page in early 1987.¹³

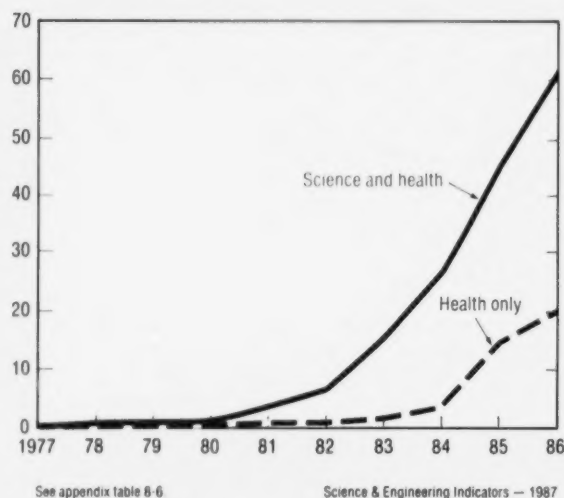
Use of Computers

The computer—a technological product that many Americans have learned to use in recent years—is an

¹²In the case of reading science magazines this is expected, since reading such magazines enters into the definition of attentiveness.

¹³*Science* (1987), p. 429.

Figure 8-1.
Weekly science and health sections in
U.S. daily newspapers



especially interesting illustration of the growing effect of science and technology on the public. Many commercial products, from toys to automobiles, contain built-in computers. Business use of computers has been developing over several decades and is now widespread. About one-quarter of adults reported that they use computers at work. (See table 8-6.) (Since no specific kind of computer was mentioned, respondents presumably were referring to a broad range of devices such as computerized cash registers and word processors in addition to more conventional computers.¹⁴) Those who do use computers at work spend the equivalent of almost 2 working days per week at their terminals on average. While attentives are more likely to use computers at work than others are, those who have computers at work use them about as much whether they are attentives or not.

Home computers have been common for a shorter time and are not as widespread. Still, 15 percent of Americans report having a computer in their homes, up from 9 percent in 1983.¹⁵ Home computers are used fewer hours per week than are business computers. (See table 8-6.)

¹⁴The estimated level of computer use at work varies widely from one survey to another, probably because of the wide variety of devices that can be considered computers. A survey of computer use in industrial R&D organizations in 1984 found that an average of 42 percent of scientists and engineers in those organizations use them. Forty-two percent of senior managers had their own terminals, while fewer lower-level managers did. See Rossini and Porter (1985).

¹⁵Miller (1983b). Another study found that 13 percent of adults, 26 percent of children aged 12-17, 22 percent of those 6-11, and 17 percent of those 2-5 had access to a home computer in 1985. See Ancarrow (1987), table 1. For more information, also see chapter 1, "Precollege Science and Mathematics Education."

Table 8-6. Reported use of a computer at work and at home: 1985

Activity	Total public	Attentive public	Interested public	Remaining public
Use computer at work and at home (percent)	6	12	5	4
Average hours per week at work	13.9	12.7	14.6	14.9
Average hours per week at home	5.1	5.3	4.7	5.1
Use computer at work only (percent)	19	23	22	16
Average hours per week at work	14.8	15.3	14.5	14.7
Use computer at home only (percent)	9	11	8	9
Average hours per week at home	1.8	1.8	3.0	1.2
Do not use computer (percent)	66	54	65	71
N =	2,005	417	517	1,071

"Do you presently own a home computer?"

"Do you use a computer in your work?"

See appendix table 8-7.

Science & Engineering Indicators—1987

Owners of home computers spend more time on them if they also have computers at work. Attentives show higher levels of home computer ownership than the rest of the public. However, the group which has only home computers and which uses them the most are not attentives, but the interested public.

In demographic terms, computer use is positively associated with higher levels of education. (See appendix table 8-7.) Interestingly, however, graduates of associate's degree programs have an especially high level of home computer use. Many of these people are technicians, computer operators, or computer programmers. Home computers are most frequently found in the 35-44 age group, while younger people are generally more likely to use a computer at work.

The Japanese respondents were also asked about their use of computers. While about 25 percent of Americans reported using a computer at work, only 12 percent of Japanese did so. This appears to be a significant difference.¹⁶ In the case of managerial and professional workers, 51 percent reported using computers at work. Among clerical and service workers this figure was 42 percent. Nine percent of the Japanese respondents reported owning home computers; the comparable figure for Americans was about 12 percent.¹⁷

¹⁶There are some differences in the definition of a computer. For example, the Japanese survey excluded word processors, and the American survey—in the case of home computers—excluded those primarily used for entertainment. The 1985 British survey found that 6 percent of respondents used typewriters with an electronic memory, 5 percent used computer-controlled machine tools, 8 percent used computer-aided design/computer-aided manufacturing (CAD/CAM) equipment, and 13 percent used other computers or terminals at work, at school, or at college. See Market & Opinion Research International Limited (MORI) (1985), p. 11.

¹⁷This number omits the American home computers that are primarily used for word processing, in order to better match the Japanese definition of computers. In Great Britain, 18 percent reported using a home computer in 1985. See MORI (1985), p. 22.

PERCEIVED RESULTS OF SCIENCE AND TECHNOLOGY

The public has various opportunities to think about scientific and technological developments and to judge how these developments are related to their own lives. Television broadcasts and newspaper articles announce new discoveries; the present and potential impacts of these discoveries on society are discussed and explored in magazine articles, sermons, personal conversations, and in many other ways. It is thus of interest to ask what judgments the public has formed about the advantages and disadvantages of science and technology, and about the changes they are likely to bring in the future. More specifically, since science and technology are known to have significant impacts on the content of work and levels of employment, it is of special interest to gauge the public's feelings about these impacts.

Benefits versus Harms from Scientific Research

The public overwhelmingly believes that scientific research has brought more benefits than harms. (See table 8-7.) Only 19 percent believe the harms exceed the benefits. This is up from 11 percent in 1979, and 14 percent in 1981,¹⁸ however, indicating some growth in the negative perception of science and technology over the last several years. Those with a college education are most likely to say that the benefits substantially exceed the harms; correspondingly, those who consider harms greater than benefits tend to have lower levels of education. (See appendix table 8-8.) There is also a discernible gender difference, with more men than women maintaining that the benefits are substantially greater than the harms. A 55-percent majority of attentives agree that the benefits

¹⁸See National Science Board (1981), p. 161, and National Science Board (1983), p. 147. Data from other years are shown in National Science Board (1985), p. 153. They are not comparable with the data shown here because the question asked in these years offered three possible answers, rather than two as here.

Table 8-7. Public assessment of beneficial versus harmful results of scientific research

Assessment	1979	1981	1985
	Percent		
Balance strongly favors beneficial results	46	46	44
Balance only slightly favors beneficial results	24	28	24
About equal ¹	13	11	4
Balance only slightly favors harmful results	7	10	13
Balance strongly favors harmful results	4	4	6
Don't know	6	1	8
N =	1,635	1,540	2,005

"People have frequently noted that scientific research has produced both beneficial and harmful consequences. Would you say that, on balance, the benefits of scientific research have outweighed the harmful results, or that the harmful results of scientific research have outweighed its benefits?"

¹ Volunteered by respondent.

See appendix table 8-8.

Science & Engineering Indicators—1987

are substantially greater than the harms. Fewer members of the interested public believe this, and still fewer members of the remaining public, but this view is still the one expressed most frequently by all three groups.

In Japan, the 1987 survey included the question "Science and technology have both their pluses and minuses, but from your standpoint which do you think are greater?" Fifty-four percent thought the pluses were greater, 8 percent thought the minuses were greater, and 29 percent considered them equal (9 percent had no opinion). Though the questions were not quite the same, it is notable that the balance of positive over negative responses was greater in Japan than in the United States (cf. table 8-7).¹⁹

These responses can be understood better by examining the individual areas of life that research is thought to have hurt or benefited. Science and technology are thought to have been especially beneficial in technological and economic areas, namely the standard of living, public health, and working conditions. (See table 8-8.) On the other hand, large minorities feel that science and technology have had negative effects on world peace and, especially, on moral values. Thus, cultural and military aspects of science and technology are viewed more negatively than are economic and health aspects. The individual's enjoyment of life involves both economic and more personal considerations; thus, the "positive effect" responses in this case fall between those received for the

¹⁹The 1985 British survey asked "Some people believe that man has gone too far in tampering with nature through scientific enquiry. Others say this kind of scientific enquiry has brought great benefits to man and should be encouraged. Which comes closest to your own view?" Thirty percent replied that science has gone too far, 53 percent that it has brought great benefits, 10 percent said "neither," and 7 percent replied "don't know." While the wording may have encouraged negative responses, there was a preponderant support for science. See MORI (1985).

technological-economic items and the personal and social items.

Four of these effects were also explored in the Japanese survey.²⁰ In general, the Japanese much more frequently answered "don't know" or "neither" when asked about the effects of science and technology in these areas. (See table 8-8.) A high frequency of "don't know" or neutral responses is commonly observed in Japanese opinion surveys, and seems to be a cultural characteristic.²¹ This should be taken into account when interpreting all survey data involving Japan and other countries. While Japanese respondents in this survey agreed with Americans that the most positive effect of science and technology has been on the standard of living, they were much less willing than Americans to accept the idea that science and technology have improved working conditions. Moreover, the Japanese were even less inclined than Americans to accept that science and technology improve morality.²²

Another view of the public's perception of benefits and risks is obtained by looking at the responses to the same question in a variety of countries. (See figure O-33 in Overview.) In 1981, a coordinated set of surveys was done in 17 countries asking whether scientific advances will help or harm mankind in the long run.²³ Among the industrialized countries, the United States showed the highest level of positive response. British, Spanish, Canadian, and Australian respondents also gave a high proportion of positive replies. The Netherlands was the only country giving more negative than positive replies. In Japan—and to a lesser extent in Belgium, Denmark, and West Germany—many respondents were unwilling to say that mankind will be either helped or hurt, opting instead for the answer "both." (See appendix table 8-9.) In the case of Japan, this may again reflect the general tendency to give neutral responses. The effects these opinions have had on public science and technology policies in these countries would make a useful subject for further study.

Expectation of Future Scientific and Technological Developments

Respondents were also asked how likely they thought it is that science and technology will produce certain

²⁰The Japanese question was "Do you think that the following factors have been bettered or worsened by scientific and technological developments? Or do you think they have been unchanged?" The U.S. question was "Now, I want to read you a short list of areas and for each one, please tell me if you think that science and technology have had a positive effect, a negative effect, or neither kind of effect."

²¹See Kuroda, Hayashi, and Suzuki (1986).

²²In 1982, 17 percent of respondents to a French survey said that scientific and technological development have had more favorable effects on the moral sense, 42 percent said the effects were more unfavorable, and 24 percent said neither. See Bon and Boy (1984b), p. 47. This attitude appears closer to the American than to the Japanese response.

²³For the entire list of countries surveyed, see appendix table 8-9. The Canadian part of the survey was actually done in 1982, while the Kuwaiti, Lebanese, and Australian parts were done in 1983. Since year-to-year changes tend not to be large, the opinions shown for these years should be close to current opinions. Because of differences in question wording and survey administration, the data shown for the United States on figure 8-2 are not strictly comparable with those shown for the United States in 1981 on table 8-7.

**Table 8-8. Impact of science and technology on other areas of life:
American, Japanese, and French responses**

Area and country	Positive effect	Neither	Negative effect	Don't know
	Percent			
Our standard of living:				
United States	84	6	8	2
Japan	73	18	3	5
France	79	10	7	5
The public health:				
United States	83	4	12	2
Japan	NA	NA	NA	NA
France	77	7	13	3
General working conditions:				
United States	79	8	11	2
Japan	40	29	21	11
France	76	6	13	4
The individual's enjoyment of life:				
United States	69	12	15	4
Japan	46	35	8	12
France ¹	59	12	21	8
World peace:				
United States	42	18	33	7
Japan	NA	NA	NA	NA
France	23	23	41	14
People's moral values:				
United States	25	28	41	6
Japan	5	38	42	15
France	17	24	42	18

¹ In France, the item was "the structure of daily life."

Note: N = 2,005 (United States, 1985)

N = 2,334 (Japan, 1987)

N = 1,515 (France, 1982)

SOURCES: Japan: Office of the Prime Minister of Japan (1988); United States: Jon D. Miller (1988); France: Frederick Bon and Daniel Boy (1984). Science & Engineering Indicators—1987

specific outcomes in the next 25 years or so. It is evident that the public expects continued medical developments: about one-half of the public thinks it very likely that cancer and AIDS will be curable in the next generation. (See table 8-9.) A half of the public also thinks there will be no wars in space in the next 25 years, and belief that such a conflict is unlikely to occur actually rose significantly from 1983 to 1985. On the other hand, nearly half of the public considers such wars at least possible.

Large minorities consider it very likely that there will be an accidental release of a toxic chemical causing numerous deaths and another nuclear accident such as the one at Three Mile Island.²¹ This question was asked after

²¹In the 1985 British survey, respondents were asked separately about a list of things that will and will not result from the application of science and technology over the next few years. Twenty-six percent believed that problems associated with nuclear waste will be solved; 39 percent thought they will not; 36 percent did not say either. Thirty-seven percent said there will be a major accident at a nuclear power station; 22 percent said there will not; 41 percent said neither. See MORI (1985), p. 8.

the major chemical accident in Bhopal, India, but before the nuclear accident in the Soviet Union at Chernobyl.

Opinion is almost evenly split on the accidental release of a genetically engineered microbe and on the items related to space technology. While attentives are somewhat more optimistic about space-related and medical achievements than is the rest of the public, in many areas their expectations are virtually the same as those held by others. (See appendix table 8-10.) For example, there is no significant difference between attentives and others in their expectation of chemical and nuclear accidents.

The Japanese survey also included a question about expectations for the next 25 years. (See appendix table 8-11.) The question included four possible outcomes that were the same as outcomes listed in the U.S. survey. It is notable that the Japanese ordered the likelihoods of these four outcomes in just the way that the American respondents did. The outcome considered most likely was a cancer cure, followed by a cure for AIDS, a method for processing atomic wastes, and a manned Mars landing.

Table 8-9. Public expectations concerning future outcomes

Outcome	Year asked	Very likely	Possible	Not at all likely	Don't know	N
Percent						
A cure for the common forms of cancer	1979	46	44	8	2	1,635
	1983	57	36	6	1	1,630
	1985	55	37	6	2	2,005
A cure for the disease AIDS ...	1985	49	38	9	4	2,005
Another nuclear power plant accident like Three Mile Island ...	1985	46	41	9	3	2,005
The accidental release in the United States of a toxic chemical that will result in numerous deaths	1985	42	42	12	4	2,005
A safe method for the long-term storage or disposal of waste products from nuclear power plants	1983	29	41	26	4	1,630
	1985	36	42	18	4	2,005
The placement of a scientific or mining colony on the moon ...	1985	32	39	25	4	2,005
The development of genetically engineered bacteria to eat or destroy toxic chemicals	1985	32	43	17	8	2,005
The landing of a manned mission on Mars	1985	27	41	29	3	2,005
The accidental release of a genetically engineered microbe into the environment	1985	17	50	20	13	2,005
A war in space	1983	26	36	36	2	1,630
	1985	12	34	50	4	2,005

"Do you think that it is very likely, possible but not too likely, or not at all likely that this result will occur in the next 25 years?"

SOURCES: Miller, Prewitt, Pearson (1980); Miller (1982, 1984, 1988).

See appendix table 8-10.

Science & Engineering Indicators—1987

Effect of Science and Technology on Work and Employment Levels

Employment is one of the most personal effects that science and technology has on the lives of the public. New technological developments have affected the way in which work is done and the training needed for a given job. In the aggregate, they help to determine how many employees are needed in a given field and which are the fields in which employment opportunities are available. Concerns about the effects of "automation" and/or "robots" on the nature and availability of work have been expressed widely in many countries for many years. Data capturing these concerns are available for the United States and Japan. (See table 8-10.)

There seems to be agreement between the two countries that science and technology have improved working conditions. (See table 8-10, question A.) This idea seems to be more widely accepted in the United States. The Japanese are optimistic about science and technology

making work more interesting in the future, and Americans are more optimistic still. (See table 8-10, question B.)

More vital than the *nature* of work is whether one will have a job at all. Respondents in the United States and Japan agree that automation will lead to a loss of jobs. (See table 8-11, question A.²⁶) On the other hand, Americans are split on whether technological developments are a main reason for high unemployment, with 48 percent accepting this and 45 percent disagreeing.²⁶

Although it is agreed that computers and automation will eliminate some jobs, it is widely held that they create

²⁶In the U.S., the question was whether factory automation will put many hundreds of thousands of people out of work in this country in the next 5 years. The Japanese question was "If robots and computers become widespread, many tens of thousands of people will lose their jobs."

²⁶Miller (1988).

Table 8-10. U.S. and Japanese attitudes about the effects of science and technology on working conditions

	Beneficial	Neither	Harmful	Don't know
Percent				
A. Effect science and technology have had on general working conditions:				
United States	79	8	11	2
Japan	40	29	21	11
B. Science and technology will make work more interesting:				
	Agree	Disagree	Don't know	
Percent				
United States	71	24	5	
Japan	47	37	17	

Note: N (United States, 1985) = 2,005

N (Japan, 1987) = 2,334

SOURCES: United States: Miller (1988); Japan: Office of the Prime Minister of Japan (1988)

Science & Engineering Indicators—1987

Table 8-11. U.S. and Japanese attitudes about the effects of robots and automation in employment

Country	Agree	Disagree	Don't know
	Percent		
A. Automation will put many factory employees out of work:			
United States	73	25	3
Japan	63	27	10
B. Computers and automation will create more jobs than they will eliminate:			
United States	48	44	8
Japan	13	73	14
C. Automation is necessary to meet foreign competition:			
United States	75	21	5
Japan	51	27	21

¹ Respondents were offered a list and asked which things will happen, and then separately which things will not. This percent of respondents did not mention this item either time.

Note: N (United States, 1985) = 2,005

N (Japan, 1987) = 2,334

SOURCE: United States: Miller (1988); Japan: Office of the Prime Minister of Japan (1988)

Science & Engineering Indicators—1987

others, in both technical fields and service industries. The net effect thus may still be an increase in employment. However, respondents are not all convinced of this. (See table 8-11, question B.²⁷) The Americans are about evenly divided for and against this idea, and the Japanese are distinctly skeptical.

²⁷The American question was "On balance, computers and factory automation will create more jobs than they will eliminate." In Japan, it was "The number of jobs that will increase as a result of the spread of robots and computers is greater than the number that will decrease as a result of their spread." A French survey in 1982 asked whether "In the long run, technological progress creates more employment than it abolishes." Forty-two percent agreed, 47 percent disagreed, and 10 percent did not know. This resembles the American response. See Bon and Boy (1984b), p. 42.

Even if it fails to generate more employment, many writers suggest that automation is necessary to meet competition from other countries that do automate their factories. The American and Japanese publics appear to accept this position. (See table 8-11, question C.²⁸) The Americans seem to show a higher level of belief in the need for automation, but support is also high in Japan. Part of the explanation for Japanese support of automation may be seen in their response to another question.

²⁸The U.S. question was "If we don't automate our factories, American products will be too expensive to compete successfully against products made in automated factories in Japan and Europe." In Japan, it was "If robots and computers do not become widespread, we will not be able to win in the price competition with foreign products."

The survey noted that recently, newly industrializing countries such as Korea and Taiwan have been making spectacular progress in science and technology. It then asked respondents whether they considered this a threat to Japan or not. A 57-percent majority agreed, while 27 percent disagreed, and 16 percent did not reply. Agreement was especially high among those who believed that automation is necessary in order to meet foreign competition.

The British also believe that science and technology will improve the competitiveness of their industry, but it is not clear that they consider the price worth paying. For example, they do not believe that science and technology will create more jobs than they will destroy.²⁹ While 84 percent believe that new technology is essential for their country's prosperity,³⁰ the British are about evenly split on the desirability of robots in industry.³¹ They believe more than do Americans that because of science and technology the rich get richer and the poor poorer.³² Further, they believe much less than do Americans that because of science and technology there will be more opportunities for the next generation.³³

PUBLIC ACCEPTANCE OF SCIENCE AND TECHNOLOGY

Science and technology are part of the general culture and, as such, compete with other social institutions for public prestige and acceptance. It is therefore of interest to ask whether the public trusts and admires scientists, and would be likely to support their work and endorse their testimony on public issues. It is also of interest to ask whether the public wishes or is able to think scientifically. Scientific thinking is only one of several available modes of thinking, and the scientific community especially should be aware of the extent to which such thinking has diffused among the public. Finally, the public's view of American science and technology in comparison with the efforts of other countries is another aspect of the prestige of U.S. science and technology.

²⁹See MORI (1985), p. 20. Forty-seven percent believed that the competitiveness of British industry will improve as a result of the application of science and technology, while 14 percent believed it will not. However, only 19 percent believed that more jobs will be created than destroyed by this application, while 45 percent believed they will not.

³⁰Seven percent disagreed, 7 percent neither agreed nor disagreed, and 2 percent had no opinion.

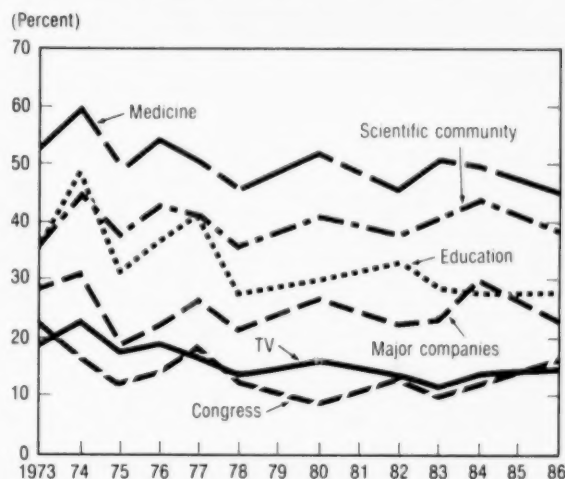
³¹Thirty-two percent favor robots, 34 percent oppose, and 34 percent did not respond to this item on the list. The French seem to be slightly more negative. In the 1982 French survey, only 13 percent were in favor of speeding up the development of robots capable of doing precise factory work rapidly; 46 percent wanted to restrain robot development, and 39 percent wanted to let these machines be put in place gradually. See Bon and Boy (1984b), p. 43.

³²In the U.S., 49 percent agree, 46 percent disagree, and 4 percent have no opinion. In Great Britain, 57 percent agree, only 16 percent disagree, and 28 percent have no opinion.

³³In the U.S., 77 percent believe this, while 19 percent disagree, and 4 percent don't know. In Britain, only 34 percent agree, 30 percent disagree, and 36 percent don't know. An internationally coordinated public opinion survey on the impact of information technology on employment is Vine (1985). The survey was done in 1985 and covered the United States and Japan, in addition to six Western European countries.

Figure 8-2.

Percent of public expressing a great deal of confidence in people running selected institutions



See appendix table 8-12.

Science & Engineering Indicators — 1987

Attitudes Toward Scientists

An important component of the public's view of science is its view of scientists themselves. Such attitudes are brought to bear when students decide whether to become scientists on the basis of their own and their parents' view of the kind of person a scientist is. Moreover, the public's acceptance of views expressed by scientists on science-related controversies is presumably influenced by their picture of the scientist as a person.

The data show that leaders of the scientific community continue to enjoy high confidence as compared with leaders of other institutions. (See figure 8-2. For the rest of the list, see appendix table 8-12.) This indicator is understood to represent the level of confidence in the institutions themselves.³⁵ While the data show fluctuations of public confidence in institutions in general—and long-term trends in the standing of certain institutions in particular—medicine has consistently led the list in terms of public confidence. The scientific community has almost as consistently been in second place. This is a very positive result from the point of view of the scientific community, especially since medicine is also a highly science- and technology-oriented profession. However, the scientific community also consistently receives the greatest number of "don't know" responses; this suggests uncertainty or a lack of familiarity with this community. Males and college graduates show relatively high levels of confidence in scientific leaders.

The responses to two other questions provide further information on the public's perception of scientists. One

³⁵Smith (1981).

Table 8-12. Public's image of scientists, by attentiveness: 1985

Statement	Total public	Attentive public	Interested public	Remaining public
	Percent			
Scientific researchers are dedicated people who work for the good of humanity.				
Agree	80	79	78	81
Disagree	16	15	18	15
Don't know	4	6	5	4
Because of their knowledge, scientific researchers have a power that makes them dangerous.				
Agree	55	48	54	57
Disagree	42	51	42	38
Don't know	4	2	3	5
N =	2,005	417	517	1,071

For each statement, tell me if you generally agree or generally disagree.

See appendix table 8-13.

Science & Engineering Indicators—1987

question was positively oriented and asked whether scientific researchers are dedicated people who work for the good of humanity. The other asked whether researchers have a power that makes them dangerous. (See table 8-12.) There was strong agreement with the positive evaluation. Moreover, there was virtually no variation by gender, education, or age, although respondents with graduate degrees were slightly less likely to share this opinion. The negative question, measuring public apprehension about the power of scientific researchers, produced a small majority expressing this concern. Responses here varied by gender and education. (See appendix table 8-13.) Since this is the one question that brought out a clearly negative reaction to scientists, further exploration would be useful to ascertain the "danger" respondents see. The negative outcomes suggested by tables 8-8 and 8-9 may provide part of the answer.

The question about scientists being dedicated people who work for the good of humanity was also asked in France and Japan. In 1982, French respondents gave almost exactly the same response as the Americans (82 percent agreed, 14 percent disagreed, 4 percent didn't know).¹⁶ In 1987, 73 percent of the Japanese agreed that scientists are striving for mankind, 16 percent disagreed, and 11 percent didn't know. The answers from all three countries to this question are broadly similar.¹⁷

On the other (negative) question, 73 percent of the French in 1982 believed that scientific researchers, because of their knowledge, have a power that can make them dangerous. Among the Japanese, 27 percent agreed that scientists are dangerous because of their abundant knowledge, while 56 percent disagreed, and 17 percent didn't know. The Japanese response to the question is more favorable to scientists than the answers from the other two countries. (Compare table 8-12.)

¹⁶See Bon and Boy (1984b), p. 17.

¹⁷In the French study, 47 percent agreed that scientists work to satisfy their curiosity more than to help people. In Japan, the acceptance of this idea was somewhat less (37 percent).

Acceptance of Scientific Thinking

In order to best communicate science- and technology-related information to the public, the scientific and technological community needs to know the degree to which the public accepts scientific thinking. Such communication may relate to health and nutrition, the safety of nuclear power plants or airline travel, or the accomplishments of the national space program. Regardless of the topic, if the public does not accept scientific thinking in general, the impact of these communications on specific issues may be lost.

No exact measures of "scientific" thinking have been agreed upon, nor is it suggested that there is an absolute standard of scientific thinking against which the respondents can be judged. What is possible, however, is to identify relatively familiar science- and technology-related topics with some popular appeal, and to compare public opinion on these topics with common scientific opinion. In this way, public acceptance of science and technology may be estimated. Six such topics have been studied. (See table 8-13.)

Broad public acceptance was found for both the concept of continental drift and the health hazards of smoking. (See table 8-13.) These results suggest that the extensive media discussion of plate movement and earthquakes has made some impression on public thinking. Similarly, the wide coverage of the smoking and health issue and the strong endorsement of the antismoking campaign by the medical community have significantly affected public attitudes. As might be expected, attentives show the most support for the scientific position, followed by the interested public and the remaining public.

On the other four items, from 43 to 47 percent of the public do not hold the usual scientific opinion.¹⁸ On only one of them (lucky numbers) do those who accept the

¹⁸This may be because of either unfamiliarity with the scientific opinion or rejection of it. At present these two reasons cannot be separated.

Table 8-13. Public opinion on scientific questions: 1985

Questions and responses	Total public	Attentive public	Interested public	Remaining public
	Percent			
Smoking causes serious health problems.				
Agree	95	97	95	94
Disagree	4	3	4	4
Don't know	1	1	1	2
The continents on which we live have been moving their location for millions of years and will continue to move in the future.				
Agree	79	89	82	74
Disagree	12	8	11	14
Don't know	9	3	7	12
In the entire universe, it is likely that there are thousands of planets like our own on which life could have developed.				
Agree	65	72	70	60
Disagree	25	21	24	28
Don't know	10	7	6	12
Human beings as we know them today developed from earlier species of animals.				
Agree	45	56	47	41
Disagree	47	40	46	51
Don't know	7	4	7	9
It is likely that some of the unidentified flying objects that have been reported are really space vehicles from other civilizations.				
Agree	43	46	42	42
Disagree	46	44	45	47
Don't know	11	10	12	11
Some numbers are especially lucky for some people.				
Agree	43	36	48	44
Disagree	53	62	49	51
Don't know	4	2	4	5
Rocket launchings and other space activities have caused changes in our weather.				
Agree	44	34	41	49
Disagree	44	58	47	37
Don't know	12	8	12	14
N =	2,005	417	517	1,071

"For each statement, please tell me if you generally agree or generally disagree."

See appendix table 8-14.

Science & Engineering Indicators—1987

scientific view significantly outnumber those who reject it. Attentives accept the scientific view more frequently than others in three of these four cases (effect of rocket launchings on the weather, lucky numbers, and human evolution). In the case of unidentified flying objects (UFO's), attentives show, if anything, a slightly greater tendency than others to believe in their existence. This is, of course, a subject which has received a great deal of fictional treatment and one which many do not consider to be settled. It also is noteworthy that a full 40 percent of the attentive public do not believe in human development from earlier animal species, and one-third believe

in lucky numbers or in the effect of human space activities on the weather. On the basis of these findings, it is fair to say that large numbers of Americans do not accept scientific views on many everyday questions.

Certain characteristics of the public help to explain these responses. For example, men are much more likely than women to accept evolution and much less likely to believe that space activities affect the weather. Age also affects the responses to the individual questions—though in widely different ways. Younger people are more likely to believe in evolution, but they are also more likely to believe in UFO's. Belief that space activities have

affected the weather tends to be found at the two extremes: among both the youngest and oldest respondents.³⁹ Educational level is, as always, strongly associated with acceptance of the usual scientific opinion. The single exception is belief in UFO's, where there is only a slight variation of response with educational level, and the frequency of a "not sure" response is especially high at all educational levels. Even at the highest educational level, however, about one-fourth of Americans with graduate degrees believe space activities affect the weather, believe in lucky numbers, or do not believe in evolution.

The Japanese public has interesting similarities and dissimilarities in its opinions on these questions. (See table 8-14.) Both publics are strongly in agreement about the dangers of tobacco and about the reality of continental drift. Regarding life on other planets and UFO's, the Japanese show lower levels of acceptance and higher levels of "don't know" responses than the Americans surveyed.⁴⁰ The greatest disagreement concerns the questions regarding evolution, where the Japanese showed much higher levels of acceptance and lower levels of rejection than did the Americans. Differences of question wording in the two surveys may be significant. Even so, among the five questions common to the two surveys (compare table 8-13 with table 8-14), the evolution question ranks third on the Japanese list in terms of acceptance but only fourth or fifth on the American list. This is the only item of the five in which the Japanese and American ordering of the items is different, so that there is a genuine difference between the two publics in terms of accepting evolution.

Limits and Alternatives to Scientific Thinking

The public's acceptance of scientific thinking can also be seen in its view of the scope and limits of science. (See table 8-15.) For example, public reaction on two issues has been studied: scientific understanding of the human mind and alternative medicines not recognized by science. Both of these should probably be thought of as areas in which science has much to learn and on which it may develop clearer positions in the future. A majority of respondents agreed that the human mind is not as accessible to science as is the physical world. Even atten-

tives support this position. A similar view was expressed in 1979, when only 23 percent agreed that we can, by scientific study, find out "just about everything" about human behavior. (Another 68 percent said "some things but not others."⁴¹) A large majority agrees that there are good ways of treating sickness that medical science does not recognize.⁴² These two questions suggest that there is an area of personal life and values in which the public feels that science does not have the last word.

Astrology is a method of analyzing human characters and of predicting the future that scientists generally consider to have been refuted by the development of science. Adherence to astrology thus is another indicator of acceptance (or nonacceptance) of scientific thinking. About 15 percent of the public reads astrology reports "every day" or "quite often." In 1979, 21 percent reported doing this.⁴³ Only 8 percent said they decide to do or not do something because of their astrological forecast for that day. (See table 8-15.⁴⁴ The figure in 1979 was 5 percent; the rise from 1979 to 1985 is statistically significant at the 95-percent level.) Belief in astrology therefore is not nearly as widespread as the belief that science has limitations with regard to the human mind and the belief in alternative medicine. There is some confusion about astrology's status as a science: 8 percent of the public regard astrology as "very scientific" and 31 percent regard it as "sort of scientific."⁴⁵ If the public is not clear about what is and is not a science, then it also may not be clear on what views are regarded as scientific. This may help to explain the lack of acceptance of scientific thinking illustrated on table 8-13.

Belief in the limits of science is broadly distributed in the population. In terms of age, for example, it is the youngest group (age 18-24) and the oldest group (65+) that believe most in astrology and in the limits of science in understanding the human mind. Thus, belief in the limits of science is not simply associated with an older generation possibly clinging to outdated, nonscientific values. There is also a youthful component that shares

³⁹For a study of the acceptance of pseudosciences by various elements of the French public, see Boy and Michelat (1984), pp. 1560-1567. On the acceptance of parapsychology and similar phenomena in the United States, see Greeley (1987), pp. 47-49.

⁴⁰The 1982 French survey found 33 percent believing in UFO's, 57 percent not believing, and 11 percent "don't know's." See Bon and Boy (1984b), p. 9. This is slightly more skeptical than the American and Japanese responses.

⁴¹See National Opinion Research Center (1980), p. 254. The 1982 study of the French population found 36 percent who disagreed with the statement that science will make it possible to understand the functioning of the human mind completely; 56 percent accepted some degree of possibility that this may happen, and 9 percent had no opinion. See Bon and Boy (1984b), p. 13. In the 1987 Japanese study, 85 percent agreed that even if science and technology develop, they cannot explain man's mind. Eight percent disagreed and 6 percent had no opinion. There are differences of questions wording—especially regarding the French question—but the Japanese response seems more skeptical about the capabilities of science than does the American response.

⁴²In the French study, 54 percent said that there certainly or possibly are illnesses that it is better to treat by means other than medicine. Thirty-seven percent disagreed and 10 percent had no opinion. See Bon and Boy (1984a), p. 13. In the Japanese study, 73 percent agreed that for some illnesses, it is better to be treated by methods other than modern medicine; 18 percent disagreed and 9 percent had no opinion. The Japanese response seems quite similar to the American, while the French response seems more supportive of the exclusive claims of medical science.

⁴³See National Opinion Research Center (1980), p. 276. Some difference between the questions used in the two years should be noted.

⁴⁴Similarly, 8 percent of the French population reported in 1982 that they take account of horoscopes in their lives "always" or "often." See Bon and Boy (1984b), p. 10, and Bon and Michelat (1984). Thirteen percent of Japanese respondents stated that they change their actions according to their horoscope for a given day. In France and Japan, interest in astrology increases the younger the respondent is; in the United States, interest increases among both the youngest and the oldest respondents.

⁴⁵Fifty-seven percent regard it as not at all scientific. In France, astrology seems to be even more widely respected, with 53 percent stating that it is a science and only 30 percent that it is not. The rest say it depends on the case (8 percent) or don't know (8 percent). See Bon and Boy (1984b), p. 11.

Table 8-14. Japanese public's opinion on scientific questions: 1987

Questions	Agree	Disagree	Don't know
	Percent		
Tobacco has a very bad effect on human health	90	8	2
The continents are moving slowly over the course of many millions of years	78	5	17
Humans have evolved from animals	75	12	13
Just as on earth, there are a great many planets in the universe on which life forms exist	49	22	29
UFO's are real	34	35	31
N = 2,334			

"What do you think of the following matters?"

SOURCE: Office of the Prime Minister of Japan (1988)

Science & Engineering Indicators—1987

Table 8-15. Public views of the limits of science: 1985

	Total public	Attentive public	Interested public	Remaining public
	Percent			
Scientists will never be able to understand the working of the human mind as well as they understand the physical world.				
Agree	59	52	60	62
Disagree	35	43	36	31
Don't know	6	5	5	7
There are some good ways of treating sickness that medical science does not recognize.				
Agree	75	72	76	76
Disagree	17	21	16	17
Don't know	7	6	7	7
Would you say that astrology is . . .				
Very scientific	8	6	9	9
Sort of scientific	31	30	30	31
Not at all scientific	57	60	59	55
Don't know	4	4	2	5
Do you sometimes decide to do or not do something because your astrological signs for the day are favorable or unfavorable?				
Yes	8	8	8	8
No	88	90	88	86
Don't know	4	2	4	6
N =	2,005	417	517	1,071

See appendix table 8-15.

Science & Engineering Indicators—1987

some of these doubts.¹⁶ No gender differences are significant, except for the larger number of women who act on astrological forecasts. Education is strongly related to belief in astrology; 17 percent of those without a high school education sometimes act on astrological forecasts. This includes 13 percent of the men without a high school

education and 22 percent of the women.¹⁷ Similarly, those with lower levels of education are more often convinced that the human mind is inaccessible to science. The question about treatments that medical science does not recognize has virtually no dependence on demographics: about three-quarters of every group surveyed (as shown on appendix table 8-15) believe that there are good methods of treating illness outside medical science.

¹⁶For a discussion of this phenomenon in the French context, see Boy and Michelat (1984).

¹⁷Miller (1988).

Table 8-16. Public perception of U.S. standing in science and technology in comparison with other countries: 1985

Area and country	Percent considering the U.S.			
	Ahead	Same	Behind	Don't know
	Percent			
Basic scientific achievements:				
Japan	36	30	29	6
Soviet Union	43	33	15	8
West Germany	58	27	7	7
Great Britain	70	18	3	8
France	75	14	3	8
Military technology:				
Soviet Union	33	40	20	6
West Germany	70	21	3	5
Japan	73	16	5	5
Great Britain	76	16	1	6
France	80	12	2	6
Civilian or industrial technology:				
Japan	11	18	66	4
West Germany	49	35	10	6
Great Britain	69	21	3	7
France	73	18	3	6
Soviet Union	75	15	4	6
N = 2,005				

"In terms of basic scientific achievements, would you say that the United States is ahead of West Germany, behind West Germany or at about the same level?"

See appendix table 8-16.

Science & Engineering Indicators—1987

U.S. Versus Foreign Science and Technology

Besides considering public acceptance of scientific thinking in general, the survey measured the public's views of American science and technology in comparison with the efforts of other countries. The resulting information reflects the influence on public opinion of news items about unfavorable changes in the balance of trade, weaknesses in the U.S. educational system, Nobel prizes received by Americans, and foreign efforts to acquire U.S. military technology. The question was asked separately about basic science, military technology, and industrial or civilian technology; rather different responses were received in each case. (See table 8-16.)

With regard to basic science, the majority agrees that the U.S. is ahead of Germany, France, and Britain. The most common opinion is that the U.S. is also ahead of the Soviet Union and Japan. Many think, however, that the U.S. is at about the same level as or even behind these two countries.¹⁸ For this question, the attentives have the greatest confidence in U.S. achievements, the interested public the next highest level of confidence, and the remaining public the least. (See appendix table 8-16.)

With respect to military technology, high percentages believe that the U.S. is leading the other noncommunist

countries, including Japan. On the other hand, the most common opinion about the Soviet Union is that it is on the same level as the United States. Fewer Americans think the U.S. is leading the Soviet Union in military technology than in basic science. Except in the case of the U.S.S.R., there is little difference between the responses of the attentive and the interested public on this question. Both groups, however, are more optimistic about U.S. accomplishments than is the remaining public.

In the case of industrial or civilian technology, the responses are quite different. A large majority thinks the U.S. is behind Japan; this response does not occur with any other field or any other country. Majorities put the U.S. ahead of Britain and France; there is weaker agreement that the U.S. is ahead of West Germany. There is a clear belief that the U.S. is leading the U.S.S.R., which is not the case when speaking of basic science or military technology. On this question, there was much less difference of opinion among the attentives, the interested public, and others. Only with regard to France and Britain is there a significant gap among the groups: it occurs between the interested public and the remaining public.

These results show that there is a general feeling that the U.S. leads France, Britain, and—to a lesser extent—West Germany in science and technology.¹⁹ U.S. superi-

¹⁸A CBS News/*New York Times* poll from September 15-19, 1985 found 14 percent saying that the Soviet Union is better than the United States in scientific research, while 67 percent think the U.S. is better.

¹⁹The 1982 French study found that the French consider themselves behind the Americans, Japanese, Soviets, and West Germans in scientific and technical accomplishments, but at the same level as or ahead of the British. See Bon and Boy (1983), p. 52.

ority to West Germany is considered greatest in military technology. This may be because that country is not a nuclear power, yet West Germany is considered stronger than France and Britain, which are nuclear powers.

With respect to Japan and the Soviet Union, it makes a great difference whether one is talking about basic science, military technology, or civilian technology.⁵⁰ Japan is given high marks in basic scientific research, but as a non-nuclear power with minimal armed forces, it is seen to be well behind the U.S. in military technology. The public has reacted very strongly to the Japanese achievement in technology and trade by placing Japan far ahead of the United States in industrial technology. The high rating given to Japan in basic science may partly reflect the American public's perception of this success in technology and trade. The Soviets are also given relatively good marks in basic scientific research. But, unlike the Japanese, their military technology is rated higher than their ranking in basic research would suggest, while their civilian technology is rated lower.

The Japanese public, in the 1987 survey, were also asked to compare various countries with respect to various aspects of science and technology. The same six countries discussed above were ranked from 1 to 6 according to their degree of progress in basic science and technology, industrial technology, and technology related to everyday living.⁵¹ (See table 8-17. For the average rankings, see appendix table 8-17.)

The Japanese consider the United States to be clearly ahead of them in basic science and technology. They consider themselves ahead of all the other countries, however, with the Soviet Union the closest competitor. This is very similar to the ranking that Americans give to these countries with respect to basic scientific achievements (see table 8-16), except that Americans are not as convinced that their country is ahead of Japan. Although the Japanese consider the United States to be leading in all three aspects of science and technology (see appendix table 8-17), it is with respect to basic science and technology that the United States is given the greatest advantage relative to the other countries.

With respect to industrial technology, the Japanese again consider the United States to be leading Japan, but only by a very small margin.⁵² Other countries are far behind. This is the area in which the Japanese rank themselves closest to the United States. (See appendix table 8-17.) This ranking, however, is nothing like the American view that Japan is clearly leading in civilian or industrial technology. (See table 8-16.)

The Japanese study also asked for a ranking of countries regarding technology related to everyday living.

The United States was clearly placed ahead of Japan in this area, in spite of Japanese accomplishments in consumer electronics and other household products. In this case, the Soviet Union was rated the lowest of the six countries. This is similar to the U.S. survey, which ranked the Soviet Union lowest in civilian or industrial technology. (See table 8-16.)⁵³

SCIENCE AND TECHNOLOGY POLICY AREAS

Funding for Basic Research

A number of specific policy areas were selected for special study. These supplement the rather broad questions discussed above by moving away from science and technology in general and into matters of practical concern. For example, 79 percent of the public believe that the Federal Government should support research that advances the frontiers of knowledge, even if this research brings no immediate benefits. (See table 8-18.) The public therefore does not expect all Federal research funding to be devoted to specific applications. Stronger support for basic research funding is found among more educated people, as in other cases, and also among those aged 25-34. (See appendix table 8-18.)

Restriction of Research

Another policy issue involves the public's wish that scientists not be allowed to conduct research on certain topics. The freedom to select their own research questions is considered a precious right by most scientists: it is recognized, however, that the public has a growing interest in what research is conducted and to what ends. Given a list of research areas, the public would not like to see research prohibited in most of them; attentives are against the restraint even more than are others. (See table 8-19.)⁵⁴ One exception to this, however, is research designed to create new biological or chemical weapons, which about two-thirds of each group is willing to restrain. Also, in 1983, about as many were opposed to research that would enable parents to select the sex of their child. (See appendix table 8-19.) Another area provoking strong resistance is the kind of study that might lead to the creation of new life forms. The response to this question seems to depend strongly on question wording. Opposition is considerably greater when there is no specific mention of plant and animal life. (See appendix table 8-19.) In this case, respondents seem to be reacting to a vague notion of some nondescript life form.

It is notable that there is no widespread opposition to the controversial practice of medical experimentation on animals. This is true even for such domestic animals and primates as dogs and chimpanzees. (See appendix table 8-19.) An Associated Press poll in 1985 found strong

⁵⁰The responses on table 8-16 suggest that the public is sometimes able to make the distinction between science and technology.

⁵¹Because of the way the question was asked, one country could not be on the same level as another, so that there is no column labeled "same" on the table.

⁵²More detailed data show that 43 percent of respondents ranked the United States first, and the same percent ranked Japan first. However, 38 percent ranked the United States second, while only 28 percent ranked Japan second. Consequently, the United States has a small lead in the average rankings. (See appendix table 8-17.)

⁵³Thus, the Japanese survey seems to have split the U.S. survey item on civilian or industrial technology into two items: industrial technology and technology related to daily living.

⁵⁴In many of these cases, respondents may be evaluating the stated outcomes of the research, rather than the desirability of curbing the research itself. On the response of attentives, see Miller (1988).

Table 8-17. Japanese public's perception of Japan's standing in science and technology in comparison with other countries: 1987

Area and country	Percent considering Japan		
	Ahead	Behind	Don't know
Basic science and technology:			
United States	20	73	7
Soviet Union	53	37	9
West Germany	60	28	12
Great Britain	76	11	13
France	78	8	14
Industrial technology:			
United States	46	48	7
West Germany	72	15	14
Soviet Union	74	15	11
Great Britain	78	7	16
France	79	4	16
Technology related to everyday living:			
United States	37	55	8
West Germany	66	20	15
Great Britain	71	14	15
France	72	12	16
Soviet Union	77	10	13
N = 2,334			

"For each of the areas listed below please rank the following countries according to their degree of progress."

See appendix table 8-17.

Science & Engineering Indicators—1987

Table 8-18. Public support for basic scientific research, by attentiveness: 1985

	Total public	Attentive public	Interested public	Remaining public
	Percent			
Even if it brings no immediate benefits, scientific research which advances the frontiers of knowledge is necessary and should be supported by the Federal Government.				
Agree	79	88	83	73
Disagree	16	10	15	19
Don't know	5	3	3	7
N =	2,005	417	517	1,071

See appendix table 8-18.

Science & Engineering Indicators—1987

support for experimentation on animals for the purposes of research on specific diseases (81 percent), basic research (72 percent), and allergy testing (61 percent).⁵⁵ While 76 percent of respondents thought that animals have rights, 38 percent of those with that opinion believed that the use of animals in medical research does not violate those rights. On the other hand, 46 percent of those believing animals have rights—or 35 percent of the entire sample—believed that experimentation does violate animal rights. This is similar to the 30 percent on table 8-20 who do not believe that scientists should be

allowed to conduct such studies. The AP study found that approval for animal experimentation varies with the type of animal, ranging from rats (88 percent) and rabbits (77 percent), to monkeys (69 percent), cows (58 percent), and dogs (55 percent).⁵⁶

⁵⁵The British public seems more opposed to experimentation on animals. When asked about medical research using animals to test drugs, 26 percent in 1985 mentioned this as something they favored developing further, 46 percent mentioned it as something they did not favor, and 27 percent did not respond. See MORI (1985), p. 9. By comparison, 63 percent of the American respondents in 1985 said that scientists should be allowed to conduct studies on animals under stated conditions. (Cf. table 8-19.)

⁵⁶Associated Press/Media General (1985).

Table 8-19. Percent of U.S. and Japanese publics willing to allow research to be conducted in certain areas

Subject and country	Should be allowed	Should not be allowed	Don't care, ¹ don't know
	Percent		
Studies that might enable most people in society to live to be 100 or more:			
United States	68	26	6
Japan	20	51	29
Studies that cause pain or injury to animals like dogs and chimpanzees, but which produce new information about human disease or health problems:			
United States	63	30	7
Japan	NA	NA	NA
Studies that might discover intelligent beings in outer space:			
United States	64	29	6
Japan	21	49	30
Studies that might lead to precise weather control and modification:			
United States	60	36	4
Japan	36	44	20
Studies that might allow scientists to create new forms of plant and animal life:			
United States	52	42	6
Japan	10	67	22
Studies that are designed to create new biological or chemical weapons:			
United States	29	66	6
Japan	NA	NA	NA
N (United States, 1985) = 2,005			
N (Japan, 1987) = 2,334			

¹ This response was explicitly offered to the respondents in the U.S. survey. In the Japanese survey it was not, but was recorded if the respondent offered it. This difference would tend to increase the relative numbers of Americans giving this answer.

SOURCES: Japan: Office of the Prime Minister of Japan (1987); United States: Miller (1988)

See appendix table 8-19.

Science & Engineering Indicators—1987

The Japanese public is more willing than the American public to stop research in certain areas. (See table 8-19.) Four questions were asked paralleling those in the American survey.⁷⁷ In each case, more respondents wished to stop the research than wished to pursue it.⁷⁸ The Japanese response thus was more negative than the American in every case. The Japanese were most negative about research to create new life forms, which was also an area of concern to Americans.⁷⁹ On the other hand, the

Japanese gave their highest support to research designed to lead to weather control.

Government Regulation of Science and Technology

A similar question has to do with the proper level of regulation of scientific and technological activities by government. The reply can serve as an indicator of the level of public comfort or discomfort regarding those

⁷⁷The American question was "For each study, please tell me whether you think scientists should or should not be allowed to conduct that kind of research. If you don't care one way or the other, just give that answer." In Japan, the question was "Do you think the following types of research should be pursued? Or should they be stopped?"

⁷⁸There was also quite a high level of "don't know" responses, so that altogether the responses supporting the several areas of research were distinctly lower than in the American survey.

⁷⁹The British also have strong feelings about such research. When asked whether they favored further developments in cross-breeding of different species of animals, only 7 percent responded affirmatively. Sixty-eight percent mentioned this as a development they would oppose being further developed, and 27 percent did not mention this subject. See MORI (1985), p. 9. This was the least favored of the 26 possible developments offered.

Table 8-20. U.S. and Japanese opinions concerning present levels of government regulation of various areas of science and technology

Area	Too low	About right ¹	Too high	Don't know
	Percent			
Use of food additives:				
United States	38	25	30	7
Japan	79	12	3	6
Construction of atomic power plants:				
United States	29	34	30	7
Japan	54	29	6	11
Manufacture of new pharmaceuticals:				
United States	21	55	16	8
Japan	54	23	13	10
Genetic engineering research:				
United States	20	42	16	22
Japan	42	26	10	21
Basic research:				
United States	17	56	12	15
Japan	18	46	16	19

N (United States, 1985) = 2,005

N (Japan, 1987) = 2,334

United States: "I'm going to read you a short list of activities, and for each one I'd like for you to tell me whether you think that the present level of governmental regulation is too high, too low, or about right."

Japan: "For the following issues, do you think that government regulations should be tightened or loosened?"

¹ This response was offered explicitly to the respondents in the U.S. survey. In the Japanese survey it was not, but was recorded if the respondent offered it. This difference would tend to increase the relative numbers of Americans giving this answer.

SOURCES: United States: Jon D. Miller (1988); Japan: Office of the Prime Minister of Japan (1988)

Science & Engineering Indicators--1987

activities. Both the Japanese and American publics were asked whether the present level of regulation in their countries is too low or too high in certain areas. (See table 8-20.) Both groups agreed that the level of regulation in the area of basic research is about right, making this the least feared area of activity.⁶¹

In the other cases, the Japanese showed notably more desire for increased regulation than did the Americans. Japanese are especially concerned about chemical food additives; they also show a strong desire for more regulation of nuclear power plants. In both of these cases, Americans are about equally split regarding more or less regulation.⁶² With regard to pharmaceutical manufacture and genetic engineering research, Americans still more strongly tend to accept the status quo, with large numbers not wishing to see any change and the remainder about equally divided for more and for less regulation. For these two technologies also, there seems to be a much

greater concern among the Japanese, and more desire to see increased regulation.⁶³

Advantages versus Disadvantages of Various Technologies

The American respondents were asked to assess three policy areas in terms of the balance between the benefits and harms they have brought. In all three cases, there is more public support than resistance although nuclear power shows an amount of resistance nearly equal to the amount of support. (See table 8-21.) Nuclear power is also the only area where attentives have a high level of resistance and where there is not a greater level of support among attentives than among others. However, large minorities also express negative assessments of space exploration and genetic engineering.

These reactions also can be studied in terms of respondents' demographic characteristics. (See appendix table 8-20.) Women are more critical of all three technologies than are men, especially in the case of nuclear power. Education is strongly correlated with support of

⁶¹Since basic research and genetic engineering research received large numbers of "don't know" responses from both the Japanese and Americans, it is fair to surmise that these are relatively unfamiliar areas for many people.

⁶²The 1982 French survey found only 21 percent in favor of adding preservatives to foods, while 75 percent were opposed and 4 percent had no reply. See Bon and Boy (1984a), p. 33. Thus the French seem to share the Japanese concern on this subject.

⁶³It should be noted that the American survey was performed before the accident at the Soviet nuclear plant at Chernobyl, while the Japanese survey was performed after it. Possibly this fact helps to explain the more negative Japanese responses.

Table 8-21. Public assessment of three policy areas, by attentiveness: 1985

Area and assessment	Total public	Attentive public	Interested public	Remaining public
	Percent agreeing			
Space exploration:				
Benefits greater than costs	53	64	57	47
Benefits equal costs ¹	2	2	4	2
Costs greater than benefits	40	29	35	46
Don't know	5	5	4	5
Genetic engineering research:				
Benefits greater than risks	49	56	52	45
Benefits equal risks ¹	2	2	1	2
Risks greater than benefits	39	35	35	41
Don't know	10	6	11	12
Nuclear power:				
Benefits exceed risks	49	49	52	48
Benefits equal risks ¹	1	1	1	2
Risks exceed benefits	45	48	42	44
Don't know	4	2	5	5
N =	2,005	417	517	1,071

"In your opinion, have the costs of space exploration exceeded its benefits, or have the benefits of space exploration exceeded its costs?"

¹ Volunteered by respondents.

See appendix table 8-20.

Science & Engineering Indicators—1987

space exploration and genetic engineering research.⁶³ In the case of nuclear power, there is no strong relationship between education and one's benefit/risk assessment; there is, however, a strong trend with age, with younger respondents being more critical.

REACTIONS TO CHALLENGER AND CHERNOBYL ACCIDENTS

Technological disasters like the Challenger and Chernobyl accidents may influence general public perceptions regarding science and technology. The main survey reported in this chapter was performed in November-December of 1985. To capture information related to these major events, two supplementary surveys were conducted. The first supplementary survey was scheduled in response to the January 28, 1986, explosion of the Space Shuttle Challenger. To investigate the effects of this accident on public opinion, the respondents interviewed in late 1985 were reinterviewed immediately after the accident, in January-February of 1986. At the time of this supplementary survey, the accident was fresh in people's minds and the President had just addressed the Nation on television, strongly supporting the continuation of the space program.

Several months later, the Rogers Commission report was published, reinforcing news reports about defective O-rings in the rocket boosters and management failings as having contributed to the accident. To measure the effect on public opinion of this information, and to deter-

mine whether the first reactions to the accident had persisted, a second supplementary survey was done in June-July of 1986.

Between these two supplementary surveys, another technological disaster came to public attention. In April 1986, the Soviet nuclear power plant at Chernobyl experienced a major accident, and released radioactive materials into the environment. The June supplementary survey thus provided an opportunity to measure changes in attitudes toward nuclear power also. Both supplementary surveys were able to take advantage of the baseline survey that had been done in late 1985, before either accident had occurred.

Reactions to Space Shuttle Accident

In February 1986, right after the Challenger accident, only a minority considered it a major setback for the space program, and nearly everyone thought the manned shuttle flights would be resumed. (See table 8-22.) With regard to the accident's causes, people were about evenly divided as to whether there was a basic design error or a flaw that might have led to the explosion. A majority believed that accidents could be expected from time to time in such complex machines as the shuttle and that the problems that had caused the accident would be found and corrected so that the shuttle program would continue. Soon after the explosion, the suggestion was made that manned flights be de-emphasized in favor of unmanned vehicles. Even the explosion did not lead to a majority favoring this alternative. About one-half were willing to see Federal funds for the program increased if they are needed to modify the shuttle program or get it back on schedule. A large majority said

⁶³Genetic engineering research also gets the highest number of "don't know" responses: these are concentrated among older respondents and those with the lowest levels of education.

Table 8-22. Public reactions to the Shuttle Challenger accident

	February 1986	June 1986
	Percent agreeing	
Accident was a major setback	37	66
Increase Federal funds for shuttle if needed	50	49
Accident reflects basic design flaw	50	78
Accidents will occur from time to time	83	82
Manned flights should be reduced	31	43
Shuttle is outstanding example of U.S. technology	97	97
Manned flights will be resumed	98	98
N =	1,111 ¹	1,111

¹ Although the February 1986 sample was greater than 1,111, the results shown here apply to the same 1,111 people who responded in June 1986.

Note: For question wording see appendix table 8-21.

See appendix table 8-21.

Science & Engineering Indicators—1987

the shuttle is still an outstanding example of American technology. In all, the first effect of the Challenger accident was a significant show of support for the space program.

In June 1986, after the Rogers Commission had reported, another survey was done, again interviewing the same respondents as far as possible. By this time, there had been a thorough discussion of the shuttle's technical and administrative problems. More respondents now believed that there was a basic design flaw and a majority was willing to characterize the accident as a major setback for the shuttle program. (See table 8-22.) More respondents also opted for reducing the number of manned flights. On other questions, there was very little change in opinion from February to June. The accident was attributed to the National Aeronautics and Space Administration (NASA) more often than to anyone else, and was blamed on the booster and the O-rings more than on any other cause. About 75 percent agreed that the shuttle would be safe to fly again once the rocket boosters were redesigned.⁶⁴ While a very large majority continued to believe that the shuttle is an outstanding example of American technology, the number who strongly agreed with this had dropped significantly. (See appendix table 8-21.) Overall, while the respondents had formed some more negative judgments about the causes of the accident and its severity, they continued to be strong supporters of the program.⁶⁵

Attitudes Toward Space Program and Science and Technology Generally

The February 1986 supplementary survey, conducted immediately after the shuttle accident, provided an op-

portunity to ask some of the same questions about general attitudes toward science and technology that had been asked in November 1985. During this time, the respondents had changed somewhat their evaluations of the space program in general. (See table 8-23.) The number considering the program's benefits to exceed its costs actually went up, particularly the number considering the benefits to greatly exceed the costs. The number⁶⁶ who considered the risks of nuclear energy and genetic engineering to strongly exceed their benefits went down from November to February. There was an increase in those strongly agreeing that science makes life healthier, easier, and more comfortable; that the Federal Government should support even research that brings no immediate benefits; and that new inventions will always be found to counteract the harmful consequences of technological development. The number agreeing that the benefits of scientific research exceed the risks had increased after the accident. (See table 8-23.) However, the main change here was an increase in those who said the benefits are slightly greater; the number saying they are strongly greater decreased substantially. Except for this last result, the general effect immediately after the shuttle disaster was to rally support for the space program and other aspects of science and technology.

In June 1986, the question about the benefits and risks from science was asked again. At most, from February to June a slight shift was found back to the opinion that the benefits of science are strongly greater than the risks, rather than slightly greater. (See table 8-23.) This change, however, was much smaller than that from November to February. With regard to space program costs and benefits, there was a decrease in those saying the benefits are greater than the costs and an increase in those saying the

⁶⁴ However, 30 percent thought it very likely—and 55 percent thought it possible but not likely—that there will be another shuttle accident within the next 25 years.

⁶⁵ In the June survey, 71 percent also agreed that the U.S. space program should build a space station, 53 percent said it should try to land astronauts on Mars in the next 25 years, and 50 percent said the U.S. should develop a scientific and mining colony on the moon in that time. See Miller (1987).

⁶⁶ Data discussed in the remainder of this paragraph are from Miller (1988).

Table 8-23. Effect of the Challenger and Chernobyl accidents on general public attitudes toward science and technology

	November 1985	February 1986	June 1986
	Percent		
Beneficial vs. harmful results of scientific research:			
Balance strongly favors beneficial results	47	20	22
Balance only slightly favors beneficial results	24	59	55
About equal ¹	5	4	3
Balance only slightly favors harmful results	12	7	5
Balance strongly favors harmful results	5	3	8
Don't know	7	6	5
Benefits of space program vs. costs:			
Benefits substantially greater than costs	30	37	33
Benefits only slightly greater than costs	25	28	27
About equal ¹	3	3	2
Costs only slightly greater than benefits	13	9	14
Costs substantially greater than benefits	26	16	18
Don't know	5	5	5
Benefits of nuclear power vs. risks:			
Benefits substantially exceed risks	30	23	26
Benefits only slightly exceed risks	20	30	26
About equal ¹	1	3	2
Risks only slightly exceed benefits	13	12	10
Risks substantially exceed benefits	31	26	28
Don't know	4	5	7
N =	1,111	1,111	1,111

¹ Volunteered by respondents.

Note: The same individuals were interviewed in all three surveys.

SOURCE: Jon D. Miller (1988)

Science & Engineering Indicators—1987

costs are greater. This change—while not enough to eradicate the increased support previously seen from November to February—suggests that news events after the explosion, including the publication of the Rogers Commission report, may have weakened the initial surge of support for the space program following the disaster.

Attitudes Toward Nuclear Power

Some of the results discussed above also may have been affected by the accident at the Soviet nuclear plant at Chernobyl, which occurred in April 1986, between the February and June surveys. Most respondents thought that the Chernobyl accident was due to basic design flaws in the reactor although, perhaps paradoxically, a majority also thought the operators and managers at Chernobyl were at fault. (See table 8-24.) Other paradoxes also emerge: the respondents agreed by a small majority that the U.S. and other countries will primarily depend on

nuclear sources of energy 50 years from now. At the same time, most agreed that solar energy is the best long-term solution to the energy problem. In any case, a very large majority agreed that science and technology will provide a long-term solution to the problem.

A very large majority also agreed that there are still major unanswered questions about the safety of nuclear power plants in all countries. Further, 49 percent of the public believed that another nuclear accident such as the one at Three Mile Island is "very likely" within the next 25 years; another 37 percent considered it at least possible.²² This is highly similar to the opinion expressed in late 1985—before the Chernobyl accident (See table 8-9.) A small majority felt that the risk involved in generating nuclear power should block the construction of new nuclear power plants. There was no large shift in the public's

²² See Miller (1988).

perception of the risk-benefit balance of nuclear power from the survey before the Chernobyl accident to the survey after. (See table 8-24.) In fact, larger shifts occurred between November 1985 and February 1986.

In summary, the Chernobyl accident elicited some expressions of uneasiness and uncertainty about nuclear power, but does not seem to have harmed the generally high level of public support for science and technology.

Table 8-24. Public reactions to the Chernobyl nuclear plant accident: June 1986

	Agree	Disagree	Don't know
	Percent		
The accident in the Soviet Union was the result of basic flaws in the design of the Chernobyl nuclear power plant	72	15	13
The operators and managers of the Soviet nuclear power plant at Chernobyl appeared to be at fault in the accident	64	19	17
Fifty years from now, all countries, including the United States, will depend primarily on nuclear power for the generation of electricity	56	38	6
Solar energy is the best long-term solution to our energy problem	63	30	7
We can depend on science and technology for a long-term solution to the energy problem	89	8	3
There are still major unanswered questions about the safety of nuclear power plants in all countries	92	6	2
The risk involved in generating nuclear power is relatively minor and should not block the construction of new nuclear power plants	41	52	7
N = 1,111			

SOURCE: Jon D. Miller (1988)

Science & Engineering Indicators—1987

REFERENCES

Ancarrow, J.S., "Use of Computers in Home Study," (Washington, DC: U.S. Department of Education, Center for Education Statistics, 1987).

Associated Press/Media General poll, Sept. 1-7, 1985.

Bon F. and D. Boy, "Évolution de l'Opinion Publique à l'Égard de la Recherche Scientifique entre 1972 et 1982," Centre de Prospective et d'Évaluation, Ministère de l'Industrie et de la Recherche (Paris: November 1983).

Bon F. and D. Boy, *La Science, la Technique et l'Opinion Publique en 1982*, Ministère du Redéploiement Industriel et du Commerce Extérieur, Ministère de la Recherche et de la Technologie, Centre de Prospective et d'Évaluation (Paris: April 1984a).

Bon F. and D. Boy, "Recherche sur les Attitudes de l'Opinion Publique à l'Égard de la Recherche Scientifique," Document No. 4 of *La Science, la Technique et l'Opinion Publique en 1982*, Fondation Nationale des Sciences Politiques, Paris, and Institut d'Études Politiques, Grenoble (April 1984b).

Boy D. and G. Michelat, "Les Français et les 'para-sciences'," *La Recherche* 161 (December 1984), pp. 1560-1567.

Greeley, A., "Mysticism Goes Mainstream," *American Health*, Vol. VI, No. 1 (January/February 1987), pp. 47-49.

Kuroda, Y., C. Hayashi, and T. Suzuki, "The Role of Language in Cross-National Surveys: American and Jap-

anese Respondents," *Applied Stochastic Models and Data Analysis*, Vol. 2, pp. 43-59 (1986).

Market & Opinion Research International Limited (MORI), "Public Attitudes to New Technology: Research Study Conducted for the Technological Change Centre" (1985).

Miller, J.D., *The American People and Science Policy: The Role of Public Attitudes in the Policy Process* (New York: Pergamon Press, 1983a).

Miller, J.D., "A National Survey of Adult Attitudes Toward Science and Technology in the United States," report prepared by the Annenberg School of Communications, University of Pennsylvania (1983b).

Miller, J.D. "The American College Student: 1985," paper presented to the 1986 annual meeting of the American Educational Research Association, San Francisco, California (1986).

Miller, J.D., "The Impact of the Challenger Accident on Public Attitudes toward the Space Program," report to the National Science Foundation (January 1987).

Miller, J.D., *Public Attitudes Toward Science and Technology, 1985* (forthcoming 1988).

National Opinion Research Center, "The Attitudes of the U.S. Public Toward Science and Technology," final report to the National Science Foundation in accordance with Contract No. C-SRS-7816839 (July 1980).

National Science Board, *Science Indicators—1980* (Washington, DC: Government Printing Office, 1981).

National Science Board, *Science Indicators—1982* (Washington, DC: Government Printing Office, 1983).

National Science Board, *Science Indicators—1985* (Washington, DC: Government Printing Office, 1985).

Office of the Prime Minister of Japan, Public Relations Office, *Public Opinion Survey on Science, Technology, and Society* (in Japanese, forthcoming 1988).

Rossini, F.A. and A.L. Porter, "The Use of Computers in Industrial Research and Development: An Analysis of the Industrial Research Institute Survey" (Georgia Institute of Technology, Office of Interdisciplinary Programs, 1985).

Science, "Science Sections in U.S. Newspapers Increase Dramatically in Past 2 Years," *Science* 235 (January 23, 1987).

Smith, T.W., "Can We Have Confidence in Confidence? Revisited," in U.S. Bureau of the Census, *Special Demographic Analyses, Measurement of Subjective Phenomena* (Washington, DC: Government Printing Office, 1981).

Vine, R.D., ed., *The Impact of Technological Change in the Industrial Democracies: Public Attitudes toward Information Technology* (Paris: The Atlantic Institute for International Affairs, 1985).

Appendix I

Appendix Tables

Appendix Tables

Page

CHAPTER 1. PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION

1-1	Achievement scores in mathematics, by age, gender, and ethnicity: 1977-86	174
1-2	Achievement scores in science, by age, gender, and ethnicity: 1977-86	174
1-3	Total scores on the Scholastic Aptitude Test for high school students intending to major in science and engineering, by race and gender: 1975-86	175
1-4	Total scores on the Scholastic Aptitude Test for high school students intending to major in science and engineering, by major discipline: 1975-86	175
1-5	Average scores on the Scholastic Aptitude Test for college-bound high school seniors, by ethnic group and gender: 1976-87	176
1-6	Average achievement scores in functions and calculus, highest-scoring 1 percent and 5 percent and all students, 12th grade college preparatory mathematics students, by country: 1981/82	177
1-7	Distribution by intended major field of students receiving highest scores on the SAT mathematics test: 1975-86	177
1-8	90th percentile scores on the Scholastic Aptitude Tests for high school students intending to major in science and engineering, by race and gender: 1975-86	178
1-9	Percentage distribution of freshmen by probable major field of study in all institutions of higher education: 1975-85	179
1-10	Earnings of individuals in teaching and in other selected occupations, by gender: 1961 and 1981	180
1-11	Distribution of elementary and secondary science and mathematics teachers by gender, for various grade levels: 1977 and 1985/86	180
1-12	Distribution of elementary and secondary science and mathematics teachers by race, for various grade levels: 1985/86	181
1-13	Percent of elementary school science teachers who have completed various college courses, by grade level taught: 1985/86	181
1-14	Percent distribution of secondary school science teachers, by grade level and number of college courses completed in science, calculus, and computer science: 1985/86	182
1-15	Percent of secondary school science teachers who have completed various college courses, by grade level taught: 1985/86	183
1-16	Percent of elementary school mathematics teachers who have completed various college courses, by grade level taught: 1985/86	184
1-17	Percent of secondary school mathematics teachers who have completed various courses, by grade level taught: 1985	184
1-18	Percent of secondary science and mathematics teachers who feel inadequately qualified to teach one or more of their courses: 1977 and 1985/86	185
1-19	Percent of elementary and secondary school science and mathematics teachers, by year in which they most recently took a college course in the subject they teach: 1985/6	185
1-20	Percent of elementary and secondary school science and mathematics teachers, by time spent in in-service education during the last 12 months: 1985/86	185
1-21	Supply of new teacher graduates, with alternative projections: 1970-92	186
1-22	Demand for new classroom teachers in elementary and secondary schools: 1970-92	186
1-23	Actual and projected public school enrollment: 1970-92	187
1-24	States which have enacted testing for initial certification of teachers: 1986	188
1-25	State-required Carnegie units (1-year courses) for high school graduation for language arts, social studies, mathematics, and science: 1958-86	189
1-26	State minimum competency testing for elementary and secondary school assessment purposes: 1985 ...	190
1-27	Mean percentage of items taught (opportunity-to-learn) to eighth grade students, by country and subject matter: 1981/2	191

1-28	Mean percentage of items taught (opportunity-to-learn) to 12th grade students, by country and subject matter: 1981/2	191
1-29	Mean percentage score of eighth grade students on the international mathematics achievement test, by country and subject matter: 1981/2	192
1-30	Mean percentage score of 12th grade students on the international mathematics achievement test, by country and subject matter: 1981/2	192
1-31	Average percent new content in three mathematics text series—comparison of the first 200 pages and the remainder of the book	193
1-32	Attitudes of 8th and 12th grade students towards mathematics in their personal lives: 1981/2	193
1-33	Attitudes of eighth grade U.S. students towards mathematics: 1981/2	194
1-34	Attitudes of 12th grade U.S. students towards mathematics: 1981/2	194

CHAPTER 2. HIGHER EDUCATION FOR SCIENTISTS AND ENGINEERS

2-1	U.S. population and college enrollment of 18- to 21-year-olds, by selected race and gender, 1970-85	195
2-2	S/E graduate enrollments of U.S. citizens in all institutions, by field, race, and enrollment status: 1980-86	196
2-3	S/E enrollment of U.S. citizens in doctorate-granting institutions by field, race, and enrollment status: 1980-86	197
2-4	Full-time S/E graduate students in doctorate-granting institutions, by field and citizenship: 1980-86	198
2-5	S/E graduate students in doctorate- and master's-granting institutions, by field and enrollment status: 1980-86	199
2-6	S/E postdoctorates in doctorate-granting institutions by field: 1980-86	200
2-7	S/E graduate students in all institutions, by gender: 1980-86	200
2-8	Region of origin of foreign students in the United States: 1974-75 to 1985-86	201
2-9	Doctorates from U.S. universities: 1960-86	202
2-10	Academic degrees awarded by degree level, S/E and non-S/E, and gender: 1960-86	203
2-11	Median total years from receipt of baccalaureate to earning the doctorate: 1960-84	204
2-12	Enrollment and source of support of full-time S/E graduate students in doctorate-granting institutions: 1980-86	205
2-13	Full-time S/E graduate students in doctorate-granting institutions, by field and type of major support: 1980-86	206
2-14	Baccalaureate sources of 1984 S/E doctorate recipients, by institutional type	207
2-15	Baccalaureate origins of Ph.D.'s for selected categories of undergraduate institutions: pre-1963, 1963-72, 1973-82	208
2-16	Type of baccalaureate institution of 1983-85 S/E doctorate recipients, by gender and race of recipients	209
2-17	Baccalaureate origins: producers of baccalaureates receiving 1984 doctorates	210
2-18	Leading baccalaureate sources of 1984 S/E Ph.D.'s, by productivity and institutional type	211
2-19	Academic doctoral scientists and engineers, by age and field: 1977, 1981, 1983, and 1985	212
2-20	Academic doctoral scientists and engineers, by primary work activity and field: 1981, 1983, and 1985	213
2-21	Academic doctoral scientists and engineers who teach, by field and rank: 1981, 1983, and 1985	214
2-22	Proportions of full-time S/E graduate students in doctorate-granting institutions, by gender, support, and field: 1986	215

CHAPTER 3. SCIENCE AND ENGINEERING WORKFORCE

3-1	Employment status of scientists and engineers, by field and gender: 1976, 1980, and 1986	216
3-2	Scientists and engineers as a percent of total U.S. workforce: 1976-86	217
3-3	Average annual percent increases in employment in science and engineering, and other economic variables: 1976-86	217
3-4	Scientists and engineers, by field and primary work activity: 1976, 1986	218
3-5	Scientists and engineers, by field and type of employer: 1976, 1986	219

3-6	Employed doctoral scientists and engineers, by field, gender, and type of employer: 1973, 1985	220
3-7	Proportion of scientists and engineers employed in industry, by sector and field: 1977, 1986	221
3-8	Technicians employed in industry, by field and sector: 1977, 1986	221
3-9	Percent of recent S/E degree recipients employed in S/E jobs, by degree and field: 1976, 1986	222
3-10	1984 and 1985 S/E degree recipients working as computer specialists in 1986, by field	222
3-11	Employment status of doctoral scientists and engineers, by field and gender: 1973, 1981, 1985	223
3-12	Employed doctoral scientists and engineers, by field, gender, and primary work activity: 1973, 1985	224
3-13	Selected employment characteristics of scientists and engineers, by field: 1986	225
3-14	Estimates and projections of the population, by selected age group: 1950-2010	226
3-15	Number of non-academic scientists and engineers per 10,000 total labor force, by gender	226
3-16	Distribution of scientists and engineers in manufacturing industry, by occupation group, selected years	227
3-17	Scientists and engineers engaged in R&D as a proportion of the total labor force population, by country: 1965-86	227
3-18	Distribution of scientists and engineers, by sector, for selected countries and selected years	228
3-19	Scientists and engineers engaged in research and development, by country: 1965-86	228
3-20	Distribution of scientists and engineers, by age group and selected countries	229
3-21	Employment status of scientists and engineers, by field and race: 1976, 1980, 1986	230
3-22	Employment status of Hispanic scientists and engineers, by field: 1986	232
3-23	First university degree by field and country: 1984 and 1985	233

CHAPTER 4. RESOURCES FOR R&D AND BASIC RESEARCH

4-1	National expenditures on research and development, by source of funds, selected countries: 1970-86	234
4-2	National expenditures for performance of R&D as a percent of GNP, by country: 1970-87	236
4-3	Estimated nondefense R&D expenditures as a percent of GNP, by country: 1971-87	237
4-4	Research and development, by performer: 1960-87	238
4-5	Research and development, by source and performer: 1960-87	239
4-6	National R&D expenditures, by character of work: 1960-87	240
4-7	National R&D expenditures, by sector and character of work: 1985	241
4-8	Academic research and development and nonacademic basic research: 1960-87	241
4-9	Nonacademic applied research: 1960-87	242
4-10	Sources of support for academic research and development: 1960-87	243
4-11	Federal obligations for academic research and development, by agency: 1967-87	245
4-12	Forms of Federal support for academic science and engineering, and NIH indirect cost ratio: 1966-86	246
4-13	Sources of support for nonacademic basic research: 1960-87	247
4-14	Federal obligations for basic research at FFRDC's, by agency: 1967-88	248
4-15	Federal obligations for basic research to intramural performers, by agency: 1967-87	249
4-16	Expenditures for basic research in industry, by source of funds: 1960-87	250
4-17	Federal obligations for basic research in industry, by agency: 1967-88	251
4-18	Federal obligations for basic research, by field: 1976-88	252
4-19	Expenditures for research and development by universities and colleges, by field: 1976-86	253
4-20	Research and development expenditures at universities and colleges, by field and source of funds: 1986	254
4-21	Basic research expenditures in industry, by field: 1973-83	255
4-22	Plant and equipment expenditures in academic science and engineering, by source of funds: 1964-86	256

4-23	Capital expenditures at universities and colleges by field and source of funds: 1972-77 and 1979-86	257
4-24	Academic officials' views regarding condition of research facilities: 1986	258
4-25	Academic officials' views on sufficiency of research space: 1986	258
4-26	Current fund expenditures for research equipment at universities and colleges, by field: 1980-86	259
4-27	Expenditures under special Federal research instrumentation programs: 1981-85	259
4-28	Awards to colleges and universities under special Federal instrumentation programs, by R&D ranking of institutions	260
4-29	Instrument needs, 1982/83, versus awards under special instrumentation programs, 1981-85	260
4-30	Condition of academic research instrument systems, by system age	261
4-31	National stock of academic instrumentation, by field	261
4-32	Instrumentation-related expenditures in academic departments and facilities, by field	262
4-33	Equipment-intensiveness of academic research by field: 1982/3	262
4-34	Instruments in shared-access facilities, by status and field: 1982/3	263
4-35	Instruments in shared-access facilities, by status, age, and field	263
4-36	Institutional coauthorship, by field and selected years: 1973, 1977, 1981, and 1984	264
4-37	Relative changes in Federal obligations for defense and nondefense R&D, by character of work: 1960-88	265

CHAPTER 5. ACADEMIC R&D AND BASIC RESEARCH: PATTERNS OF PERFORMANCE

5-1	Academic research and development and basic research by performer: 1960-87	266
5-2	Basic research expenditures by performer, for selected countries	267
5-3	Scientists and engineers in academic research and development and basic research: 1986	268
5-4	Ph.D. scientists and engineers in academic research and development and basic research: 1985	269
5-5	Doctoral scientists and engineers in research, by gender: 1975 and 1985	270
5-6	Doctoral scientists and engineers in research, by race and type of employer: 1975 and 1985	270
5-7	Foreign recipients of U.S. doctoral degrees with postgraduation plans, by field of science: 1972 and 1986	271
5-8	Proportion of Ph.D. researchers who remained employed in sector: 1973-5 to 1983-5	272
5-9	Scientists and engineers in academic research and development and basic research: 1976-86	273
5-10	Ph.D. scientists and engineers in academic research and development and basic research: 1977-1985	274
5-11	Proportion of Ph.D. researchers employed in nonprofits and government who moved to other sectors: 1973-85	275
5-12	Proportion of Ph.D. researchers who moved between university and industry: 1973-85	276
5-13	Cross-sectoral institutional coauthorship: 1973, 1977, 1981, and 1984	277
5-14	United States cross-sector citations: 1973, 1977, 1981, and 1984	278
5-15	Institutional coauthorship between the industry and university sectors, by field: 1973-84	279
5-16	Ways of relating to universities reported by business respondents, by size of company	280
5-17	Ways of relating to universities reported by business respondents, by company stage of development	281
5-18	Faculty consultants to small business, by field and type of institution	281
5-19	Most active university patent classes: 1969-85	282
5-20	U.S. doctoral degrees awarded to foreign nationals as a percent of all U.S. doctoral degrees, by field: 1960-86	283
5-21	U.S. doctoral recipients studying abroad, by field: 1967-83	284
5-22	U.S. academic exchange visas issued: 1978-86	285
5-23	Internationally coauthored articles, by field: 1973-84	285
5-24	International coauthorship, by U.S. sector: 1973, 1980-84	286

5-25	Internationally coauthored articles and all institutionally coauthored articles, by country: 1973-84	286
5-26	U.S. and world scientific and technical articles, by field: 1973-84	287
5-27	Publications in the fields and subfields of international scientific literature: 1984	288
5-28	Total references in U.S. articles and references in U.S. articles to articles from other countries, by field: 1974-84	289
5-29	Relative citation ratios for U.S. articles by field: 1973-82	290
5-30	International collaboration in Deep Sea Drilling Project research areas	291
5-31	Scientists and engineers leaving research for new activities: 1973-75 to 1983-85	292

CHAPTER 6. INDUSTRIAL RESEARCH AND TECHNOLOGICAL INNOVATION

6-1	Industry performance and funding of research and development, for selected countries: 1970-87	293
6-2	Expenditures for industrial R&D, by source of funds: 1960-87	294
6-3	Expenditures for industrial R&D, by industry: 1960-85	295
6-4	Total employment of R&D-performing companies, by industry: 1960-85	297
6-5	Federal funding of industrial R&D, for selected industries: 1980-85	298
6-6	Company funds for research and development by industry: 1970-87	299
6-7	Share of R&D funding provided by the Federal Government in selected industries: 1980-85	301
6-8	U.S. patents granted, by nationality of inventor: 1970-86	302
6-9	U.S. patents granted to U.S. inventors, by type of owner: 1970-86	303
6-10	Shares of U.S. patents granted to inventors in various countries, by product field: 1975 and 1986	304
6-11	U.S. patents granted to inventors in various countries, for selected technologies: 1975, 1986	305
6-12	Success rates of patent applications to U.S. Patent and Trademark Office, by applying country: 1975, 1981	306
6-13	U.S. employment, by size of firm: 1975-84	306
6-14	Venture capital resources, commitments and disbursements: 1978-86	306
6-15	Venture capital investments, by industry: 1984-86	307
6-16	Venture-backed initial public offerings by small firms: 1984-86	308
6-17	Number of small firms active in selected biotechnology product groups in 1986	309
6-18	Small firms active in selected biotechnology product groups in 1986, by type of ownership	310
6-19	Number of small firms active in biotechnology fields, by year of formation	311
6-20	New products first marketed in 1985, by size of firm	312

CHAPTER 7. THE INTERNATIONAL MARKETS FOR U.S. TECHNOLOGY

7-1	U.S. trade in high-technology and other manufacturing product groups: 1970-86	313
7-2	U.S. exports as a percentage of shipments, high-technology and other manufactured products: 1978-1985	314
7-3	U.S. direct investment position abroad in manufacturing in selected nations and product groups: 1966-86	315
7-4	Operations of overseas affiliates of U.S. corporations, selected high-technology manufacturing and service industries: 1984	316
7-5	Foreign direct investment position in the United States in manufacturing, by nationality of parent company, in selected industries: 1979-86	318
7-6	Foreign direct investment position in the U.S., high-technology industries: 1980-86	319
7-7	U.S. receipts and payments of royalties and fees associated with unaffiliated foreign residents: 1972-85	320
7-8	Technology sales agreements between Japan and the U.S. and other countries, new and old agreements, number of agreements, and payments made: 1975-85	322
7-9	Technology purchase agreements between Japan and the U.S. and other countries, new and old agreements, number of agreements, and payments made: 1975-85	323
7-10	Exports of high-technology products, by selected countries: 1965-84	324

7-11	U.S. trade in high-technology product groups, by region: 1978-86	326
7-12	Exports of selected high-technology products, volume and market shares, selected countries: 1975, 1984	326
7-13	Direct investment positions abroad and shares of total international direct investment, major investing countries and world total: 1973-84	327

CHAPTER 8. PUBLIC ATTITUDES TOWARD SCIENCE AND TECHNOLOGY

8-1	Various segments of U.S. public attentive to or interested in science and technology: 1985	328
8-2	Reported understanding of various aspects of science and technology: 1985	328
8-3	Actual understanding of various aspects of science and technology: 1985	329
8-4	Reported understanding of various aspects of science and technology by Japanese: 1987	329
8-5	Public using various information sources: 1985	330
8-6	Weekly science and health sections in U.S. daily newspapers: 1977-86	330
8-7	Computer use at home and at work: 1985	331
8-8	Public assessment of beneficial versus harmful results of scientific research: 1985	331
8-9	Benefits and harms from scientific advance, for various countries: 1981-83	332
8-10	Public expectations concerning future outcomes, by attentiveness: 1985	333
8-11	Japanese public expectations concerning future outcomes: 1987	334
8-12	Public indicating "a great deal of confidence" in the people running selected institutions: 1973-86	334
8-13	Public image of scientists: 1985	335
8-14	Public acceptance of scientific conclusions: 1985	335
8-15	Public views of the limits of science: 1985	336
8-16	Public considering U.S. ahead of other countries in science and technology, by attentiveness: 1985	336
8-17	Japanese public's ranking of various countries on various aspects of science and technology: 1987	337
8-18	Public support for basic scientific research: 1985	337
8-19	Public willingness to restrain scientific studies: 1979-85	338
8-20	Public assessment of three policy areas, by demographic group: 1985	338
8-21	Public reactions to Shuttle Challenger accident: February 1986 and June 1986	340

Appendix table 1-1. Achievement scores in mathematics, by age, gender and ethnicity: 1977-86

Gender and ethnicity	1977-78	1981-82	1985-86
Nine year olds			
Total	54.1	54.7	55.4
Male	53.8	54.0	55.8
Female	54.4	55.3	55.1
White	57.0	57.3	58.5
Black	40.5	42.0	46.1
Hispanic	45.2	46.8	46.6
Thirteen year olds			
Total	62.7	65.2	63.8
Male	62.6	65.3	64.1
Female	62.7	65.1	63.4
White	65.9	68.0	66.3
Black	47.6	52.1	56.6
Hispanic	51.0	57.0	54.4
Seventeen year olds			
Total	62.9	62.1	62.9
Male	65.0	63.9	64.5
Female	60.9	60.3	61.4
White	65.9	65.4	66.3
Black	44.7	45.2	48.1
Hispanic	48.7	47.6	51.0

SOURCE: Educational Testing Service, *National Assessment of Educational Progress*

See figure O-16 in Overview

Science & Engineering Indicators—1987

Appendix table 1-2. Achievement scores in science, by age, gender and ethnicity: 1977-86

Gender and ethnicity	1976-77	1981-82	1985-86
Nine year olds			
Total	54.4	57.7	58.8
Male	54.7	56.7	58.1
Female	54.1	58.6	59.5
White	57.5	60.5	62.0
Black	40.9	46.4	49.5
Hispanic	42.1	45.9	49.4
Thirteen year olds			
Total	54.5	54.8	55.1
Male	55.7	56.6	56.7
Female	53.4	53.1	53.5
White	57.2	56.9	57.6
Black	43.2	45.1	47.7
Hispanic	43.2	47.0	46.6
Seventeen year olds			
Total	71.3	68.8	71.5
Male	73.4	71.1	73.4
Female	69.2	66.7	69.6
White	73.7	71.7	74.5
Black	56.8	54.8	60.1
Hispanic	62.6	60.4	62.4

SOURCE: Educational Testing Service, *National Assessment of Educational Progress*

See figure O-17 in Overview

Science & Engineering Indicators—1987

Appendix table 1-3. Total scores on the Scholastic Aptitude Test for high school students intending to major in science and engineering, by race and gender: 1975-86

Race and gender	1975	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
SAT Verbal Scores ¹											
All White students	474	467	466	464	461	462	462	461	464	468	468
White males	470	463	463	461	458	461	461	460	465	468	469
White females	480	475	471	468	466	464	465	463	463	468	467
All Black students	361	352	354	349	351	352	361	357	357	363	363
Black males	358	352	356	351	353	355	364	360	360	367	368
Black females	365	351	351	347	349	349	357	354	354	358	357
Other students	433	414	406	402	403	400	400	359	397	403	403
All students	464	454	451	448	446	446	446	444	446	451	450
SAT Math Scores ¹											
All White students	530	528	524	521	521	520	522	523	525	527	527
White males	543	545	541	538	537	536	538	538	539	543	546
White females	505	498	494	493	495	494	495	497	501	501	496
All Black students	393	384	383	385	390	391	396	397	399	403	400
Black males	403	400	401	402	404	406	410	411	411	417	417
Black females	381	367	365	367	374	375	381	382	387	388	382
Other students	508	495	486	489	492	493	493	494	497	500	502
All students	520	514	509	507	507	507	508	509	511	514	513

¹ SAT scores range between a low of 200 and a high of 800.

SOURCE: Jerilee Grandy, "Ten-Year Trends in SAT Scores and other Characteristics of High School Seniors taking the SAT and Planning to Study Math, Science, or Engineering," unpublished report, Educational Testing Service (October 1987).

Science & Engineering Indicators—1987

Appendix table 1-4. Total scores on the Scholastic Aptitude Test for high school students intending to major in science and engineering, by major discipline: 1975-86

Intended Major Field	1975	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
SAT Verbal Scores ¹											
Math & statistics	465	464	464	459	455	456	455	452	457	459	469
Computer science	439	439	436	432	429	427	426	422	420	423	413
Physical sciences	520	518	517	516	513	515	514	513	514	521	526
Architecture environmental engineering	432	424	423	418	415	414	413	412	415	420	419
Engineering	453	451	450	448	446	448	451	450	455	456	455
Life sciences	468	461	460	457	453	455	456	457	462	467	464
Earth & environmental sciences	464	457	456	453	451	451	449	451	454	457	458
Psychology	451	444	439	435	434	433	435	437	436	440	441
Social sciences	476	449	443	443	445	446	453	454	457	461	453
Interdisciplinary other sciences	499	515	512	509	506	510	507	503	509	507	520
Total Science, Math & Engineering	464	454	451	448	446	446	446	444	446	451	450
SAT Math Scores ¹											
Math & statistics	584	588	585	580	577	572	569	572	578	578	593
Computer science	524	529	522	517	513	502	497	497	496	501	489
Physical sciences	592	595	590	586	585	580	582	583	583	587	598
Architecture environmental engineering	509	506	501	496	494	489	487	486	486	491	494
Engineering	546	550	543	540	538	537	540	543	546	548	553
Life sciences	509	500	496	493	490	489	489	494	499	505	504
Earth & environmental sciences	500	501	495	490	489	486	485	485	485	487	489
Psychology	461	455	449	447	447	447	446	449	453	455	455
Social sciences	495	465	456	457	460	461	464	468	470	475	469
Interdisciplinary other sciences	569	593	585	578	574	575	572	572	575	575	589
Total Science, Math & Engineering	520	514	509	507	507	507	508	509	511	514	513

¹ SAT scores range between a low of 200 and a high of 800.

SOURCE: Jerilee Grandy, "Ten-Year Trends in SAT Scores and other Characteristics of High School Seniors taking the SAT and Planning to Study Math, Science, or Engineering," unpublished report, Educational Testing Service (October 1987).

Science & Engineering Indicators—1987

Appendix table 1-5. Average scores on the Scholastic Aptitude Test for college-bound high school seniors by ethnic group and gender: 1976-87

Ethnic group and gender	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1987
SAT Verbal Scores ¹											
All students	431	429	429	427	727	727	726	725	726	431	430
Men	433	431	433	431	428	430	431	430	433	437	435
Women	430	427	425	423	420	418	421	420	420	425	425
Native American	388	390	387	386	390	391	388	388	390	392	393
Asian-American	414	405	401	396	396	397	398	395	398	404	405
Black	332	330	332	330	330	332	341	339	342	346	351
Mexican-American	371	370	370	370	372	373	377	375	376	382	379
Puerto Rican	364	355	349	345	350	353	360	358	358	368	360
Other Hispanic	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	387
White	451	448	446	444	442	442	444	443	445	449	447
Other	410	402	399	393	394	388	392	386	388	391	405
SAT Math Scores ¹											
All students	472	470	468	467	466	466	467	468	471	475	476
Men	497	497	494	493	491	492	493	493	495	499	500
Women	446	445	444	443	443	443	443	445	449	452	453
Native American	420	421	419	421	426	425	424	425	427	428	432
Asian-American	518	514	510	511	509	513	513	514	519	518	521
Black	354	357	354	358	390	362	366	369	373	376	377
Mexican-American	410	408	402	410	413	415	416	417	420	426	424
Puerto Rican	401	397	388	388	394	398	403	403	405	409	400
Other Hispanic	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	432
White	493	489	485	483	482	483	483	484	487	190	489
Other	458	457	450	447	449	447	449	446	450	448	455

¹ SAT scores range between a low of 200 and a high of 800.

Note: NA = Not Available.

Note: SAT scores by ethnic group were not available for 1986.

SOURCE: Educational Testing Service, *1987 Profile of SAT and Achievement Test Takers: National Report*, College Entrance Examination Board, 1987.

See figures 1-1 and 1-3.

Science & Engineering Indicators—1987

Appendix table 1-6. Average achievement scores in functions and calculus, highest-scoring one percent and five percent and all students, 12th grade college preparatory mathematics students, by country: 1981/2

Country	Top one percent	Top five percent	All students
Average scores			
Hungary	66.0	58.0	42.0
Canada (B.C.)	58.0	52.0	39.0
Canada (Ontario)	67.0	58.5	49.5
Scotland	61.0	54.0	45.0
Finland	68.0	62.0	53.0
United States	61.0	52.0	43.0
Sweden	67.0	59.0	52.0
Japan	70.0	67.0	58.0
New Zealand	66.0	58.0	52.0
Belgium (Flemish)	63.0	56.0	50.0
Belgium (French)	62.0	55.0	48.0
England/Wales	65.0	57.0	55.0
Israel	61.0	50.0	48.0

Note: Countries are arranged in decreasing order in terms of the proportion of students enrolled in advanced mathematics programs.

SOURCE: International Association for the Evaluation of Educational Achievement, *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, University of Illinois, Stipes Publishing Company (January, 1987), p. 26

See figure O-15 in Overview.

Science & Engineering Indicators—1987

Appendix table 1-7. Distribution by intended major field of students receiving highest scores¹ on the SAT mathematics test: 1975-86

Intended Major Field	1975	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Percent											
All fields	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total science, mathematics & engineering	44.9	40.4	44.0	46.0	45.5	46.6	50.4	48.8	46.0	46.1	43.9
Total science & math	32.8	25.4	26.1	26.7	24.8	25.5	27.1	26.9	25.2	25.2	22.2
Math & statistics	6.6	4.8	4.7	4.1	3.6	3.5	3.2	3.1	3.3	3.5	2.8
Computer science	2.0	2.7	3.7	4.8	5.4	6.9	8.9	10.0	8.5	6.7	4.2
Physical sciences	2.1	3.2	3.4	3.4	3.4	3.0	3.0	2.8	2.7	2.9	2.9
Life sciences	10.8	5.4	5.3	5.1	4.4	4.4	4.4	4.1	4.2	4.4	4.6
Earth & environmental sciences	0.8	1.1	1.1	1.1	0.9	0.8	0.7	0.6	0.5	0.5	0.6
Psychology	2.3	2.0	2.1	2.4	2.0	2.1	2.1	1.9	1.9	2.4	2.3
Social sciences	4.4	4.3	3.9	4.1	3.7	3.5	3.5	3.3	3.2	3.8	4.1
Interdisciplinary/other sciences	3.8	1.8	1.9	1.8	1.5	1.4	1.3	1.1	1.0	1.0	0.7
Total engineering	12.2	15.0	17.9	19.4	20.7	21.1	23.3	21.9	20.8	20.9	21.8
Architecture/environmental engineering	1.8	1.5	1.7	1.8	1.7	1.6	1.5	1.1	1.0	1.2	1.3
Engineering	10.4	13.5	16.2	17.6	19.0	19.5	21.8	20.8	19.8	19.8	20.5
Non-S/E major fields	55.1	59.6	56.0	54.0	54.5	53.4	49.6	51.2	53.9	53.9	56.1
Humanities	2.3	1.9	1.9	2.1	1.9	1.9	2.0	1.7	1.7	2.0	1.8
Pre-medicine	5.3	7.8	7.8	8.0	7.8	8.1	8.1	8.0	8.1	8.5	7.4
Pre-law	—	2.3	4.0	3.9	3.3	3.4	3.4	3.1	2.9	3.1	2.6
Business	5.1	6.7	8.0	9.7	8.9	9.2	9.5	8.5	8.3	10.3	10.9
Other non-S/E fields	42.5	41.0	34.4	30.3	32.7	30.8	26.6	29.9	32.9	30.0	33.4

¹ Students scoring higher than the 90th percentile in their ethnic/gender group.

SOURCE: Jerilee Grandy, "Trends in the Selection of Science, Mathematics, or Engineering as Major Fields of Study among Top-Scoring SAT Takers," Educational Testing Service, Final Report to the National Science Foundation (March 30, 1987)

See figure 1-6.

Science & Engineering Indicators—1987

Appendix table 1-8. 90th percentile scores on the Scholastic Aptitude Tests for high school students intending to major in science and engineering, by race and gender: 1975-86

Race and gender	1975	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
SAT Verbal Scores ¹											
White males	590	585	587	587	581	583	584	582	590	592	593
White females	580	582	580	579	575	573	576	573	573	579	581
Black males	485	482	477	474	476	481	487	486	489	491	497
Black females	468	465	462	458	461	460	472	470	467	474	482
Other students	578	565	558	558	553	549	553	549	561	571	560
All students	580	577	575	576	571	570	572	570	574	579	579
SAT Math Scores ¹											
White males	658	663	660	658	657	655	657	662	662	663	672
White females	603	605	602	599	601	596	599	605	610	610	615
Black males	523	532	525	522	524	531	535	534	539	547	549
Black females	475	479	470	468	471	486	483	485	491	497	495
Other students	630	625	621	626	626	625	627	634	642	645	650
All students	626	628	626	628	625	623	625	632	635	637	642

¹ SAT scores range between a low of 200 and a high of 800.

SOURCE: Jenilee Grandy, "Trends in the Selection of Science, Mathematics, or Engineering as Major Fields of Study among Top-Scoring SAT Takers," Educational Testing Service, Final Report to the National Science Foundation (March 30, 1987).

Science & Engineering Indicators—1987

Appendix table 1-9. Percentage distribution of freshmen by probable major field of study in all institutions of higher education: 1975-85

Probable major field of study	1975		1978		1980		1982		1983		1984		1985	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
	Percent in each field													
Agriculture/forestry	5.7	1.9	4.5	2.0	4.1	1.8	3.8	1.4	2.9	0.9	3.3	1.0	3.3	1.0
Arts/humanities	12.7	12.8	7.4	10.6	6.4	10.1	6.8	9.7	6.8	9.0	6.6	8.8	7.1	8.8
Biological Sciences	7.1	5.5	4.8	4.4	3.7	3.8	3.7	3.8	4.1	3.4	4.1	4.2	3.4	3.3
Business	20.1	17.5	25.0	23.1	22.9	24.5	22.3	25.7	22.7	26.0	25.1	27.5	25.7	27.5
Education	4.6	15.5	3.3	12.1	3.3	11.6	2.4	9.0	2.9	8.9	2.8	9.6	3.3	10.4
Engineering	14.0	1.3	18.8	2.3	21.0	3.2	22.3	3.6	20.6	3.5	20.1	3.0	19.3	3.0
Health professions (Non-MD)	1.8	13.2	2.0	14.6	1.9	13.3	1.6	17.8	2.1	14.9	2.3	13.8	2.0	11.6
Mathematics/statistics	1.1	1.1	1.1	0.8	0.7	0.6	0.6	0.7	0.8	0.8	0.8	0.9	0.8	0.8
Computer science	NA	NA	1.6	1.2	2.7	2.4	4.9	4.0	5.4	3.7	4.3	2.7	3.1	1.6
Physical sciences	4.0	1.3	3.5	1.3	3.6	1.6	2.6	1.0	2.5	1.0	2.5	1.1	2.3	0.9
Premed/predent/prevet	NA	NA	4.0	2.9	3.6	3.2	3.2	3.0	3.3	3.2	3.2	3.1	3.1	3.2
Social sciences	3.7	8.9	5.0	9.5	4.5	8.6	4.2	7.2	4.2	7.6	5.1	8.4	5.2	9.6
Other fields (tech)	10.3	6.7	7.0	2.0	8.5	2.9	9.7	4.3	9.9	3.8	7.7	2.4	7.5	2.4
Other fields (non-tech)	10.2	8.8	8.1	7.9	9.3	6.9	8.2	3.3	8.1	7.1	8.0	7.6	9.0	8.1
Undecided	4.6	5.5	3.9	5.3	3.8	5.5	3.7	5.5	4.0	5.7	4.1	6.2	4.7	6.9

Note: Totals may not equal 100% due to rounding.

SOURCE: Cooperative Institutional Research Program, *The American Freshman: National Norms for Fall 1985*, and reports with the same title for 1971-1984, University of California at Los Angeles and American Council on Education (December, 1985).

See figure 1-7

Science & Engineering Indicators--1987

Appendix table 1-10. Earnings of individuals in teaching and in other selected occupations by gender: 1961 and 1981

Occupation in longest job held during the year	Men		Women	
	1961	1981	1961	1981
	Average annual salaries			
All full-time workers	17,010	20,260	10,078	12,001
Salaried professional, total	22,437	25,350	14,903	15,631
Accountants	NA	24,437	NA	15,558
Health workers (except physicians and dentists)	NA	16,631	NA	16,827
Teachers (elementary and secondary schools)	19,792	20,249	15,888	16,056
Managers and administrators	21,211	25,425	10,370	14,820
Sales workers	18,305	22,331	7,269	11,238
Clerical workers	16,280	18,938	11,306	11,238
Craft workers	18,256	20,095	NA	12,904
Factory workers	15,657	16,948	8,972	10,301

NA = Not Available.

Note: These figures reflect occupational categories used by the Bureau of the Census up until 1981.

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Current Population Reports: Money Income of Households, Families, and Persons in the United States*, Series P-60, Nos. 39 and 137.

Science & Engineering Indicators—1987

Appendix table 1-11. Distribution of elementary and secondary science and mathematics teachers by gender, for various grade levels: 1977 and 1985/86

Course and gender	1977				1985/86			
	Grade level				Grade level			
	K-3	4-6	7-9	10-12	K-3	4-6	7-9	10-12
	Percent							
Mathematics								
Male	6	21	54	68	4	20	45	53
Female	94	76	46	32	93	79	51	46
Unknown	0	2	0	0	1	1	4	1
Science								
Male	2	33	62	74	3	23	56	68
Female	98	67	38	24	94	76	41	31
Unknown	0	0	0	0	3	1	3	1

SOURCE: Research Triangle Institute, 1985 *National Survey of Science and Mathematics Education*.

Science & Engineering Indicators—1987

Appendix table 1-12. Distribution of elementary and secondary science and mathematics teachers by race, for various grade levels: 1985/86

Course and grade level	Ethnicity Race					
	White	Black	Hispanic	American Indian, Alaskan Native	Asian or Pacific Islander	Unknown
Mathematics						
K-3	84	10	1	0	0	4
4-6	84	10	2	0	0	2
7-9	90	6	1	0	1	3
10-12	94	3	1	0	1	1
Science						
K-3						
4-6	82	9	4	0	1	4
7-9	86	8	4	0	1	1
10-12	88	6	1	0	1	4

SOURCE: Research Triangle Institute, 1985 National Survey of Science and Mathematics Education

Science & Engineering Indicators—1987

Appendix table 1-13. Percent of elementary-school science teachers who have completed various college courses, by grade level taught: 1985/86

Courses	Grade level taught	
	K-3	4-6
	Percent	
Education		
General methods of teaching	95	95
Methods of teaching elementary school science	87	88
Methods of teaching middle school science	7	20
Supervised student teaching	77	87
Psychology, human development	83	88
Computing		
Instructional uses of computers	31	37
Computer programming	11	21
Sciences		
Biology, environmental, life sciences	83	87
Chemistry	30	37
Physics	17	21
Physical science	58	61
Earth/space science	39	51
No science course	5	5
One type of science course	18	12
Biology	15	8
Physical science	2	3
Earth/space science	1	1
Two types of science courses	40	40
Biology and physical science	34	31
Biology and earth/space science	5	6
Physical science and earth/space science	1	3
All three categories of science courses	31	42
Unknown	4	2

SOURCE: Research Triangle Institute, 1985 National Survey of Science and Mathematics Education

Science & Engineering Indicators—1987

Appendix table 1-14. Percent distribution of secondary-school science teachers, by grade level and number of college courses completed in science, calculus, and computer science: 1985/86

Number of courses completed	Life science		Chemistry		Physics		Earth science		Calculus		Computer science	
					Grade level taught							
	7-9	10-12	7-9	10-12	7-9	10-12	7-9	10-12	7-9	10-12	7-9	10-12
	Percent											
0	3	7	18	6	16	13	24	27	53	44	52	57
1	6	7	12	8	23	17	20	21	20	19	24	21
2	12	6	16	14	21	23	16	17	12	16	12	10
3	5	5	13	14	15	12	9	9	7	9	4	5
4	11	5	12	14	7	10	6	6	2	5	2	3
5	7	3	8	9	3	4	6	3	1	2	1	1
6	5	3	6	7	6	5	3	3	0	1	0	0
7	4	3	2	3	1	1	1	0	0	1	1	0
8	46	60	10	26	7	15	12	6	0	2	1	2
Unknown	2	1	3	1	2	1	3	1	4	1	3	1

SOURCE: Research Triangle Institute, 1985 *National Survey of Science and Mathematics Education*

Science & Engineering Indicators—1987

Appendix table 1-15. Percent of secondary-school science teachers who have completed various college courses, by grade level taught: 1985/86

Courses	Grade level taught	
	7-9	10-12
	Percent	
Education		
General methods of teaching	94	94
Methods of teaching secondary school science	61	82
Methods of teaching middle school science	30	20
Supervised student teaching	83	79
Psychology, human development	85	87
Instructional uses of computers	33	30
Mathematics/computer science		
College algebra, trigonometry, elementary functions	75	78
Calculus	41	53
Differential equations	16	25
Probability and statistics	44	44
Computer programming	33	33
Life sciences		
Introductory biology	91	85
Botany, plant physiology, etc.	70	73
Cell biology	54	58
Ecology, environmental science	62	63
Genetics, evolution	55	64
Microbiology	48	53
Physiology	63	65
Zoology, animal behavior, etc.	64	71
Chemistry		
General chemistry	76	92
Analytical chemistry	30	47
Organic chemistry	51	70
Physical chemistry	21	32
Biochemistry	25	34
Physics		
General physics	73	81
Electricity and magnetism	18	28
Heat and thermodynamics	16	24
Mechanics	15	26
Modern or nuclear physics	12	23
Optics	11	18
Earth/space sciences		
Astronomy	40	36
Geology	56	49
Meteorology	27	20
Oceanography	26	19
Physical geography	39	25
Other		
History of science	21	23
Science and society	18	16
Engineering	8	12

SOURCE: Research Triangle Institute, 1985 *National Survey of Science and Mathematics Education*

Science & Engineering Indicators—1987

Appendix table 1-16. Percent of elementary-school mathematics teachers who have completed various college courses, by grade level taught: 1985 86

Courses	Grade level taught	
	K-3	4-6
	— Percent —	
Education		
General methods of teaching	94	93
Methods of teaching elementary school mathematics	90	90
Methods of teaching middle school mathematics	14	27
Supervised student teaching	82	83
Psychology, human development	83	87
Instructional uses of computers	30	34
Mathematics/Computer science		
Computer programming	17	24
Mathematics for elementary school teachers	89	90
Mathematics for secondary school teachers	11	21
Geometry for elementary or middle school teachers	17	21
College algebra, trigonometry, elementary functions	30	37
Calculus	8	12
Upper division geometry	5	7
Probability and statistics	21	27

SOURCE: Research Triangle Institute, 1985 *National Survey of Science and Mathematics Education*
Science & Engineering Indicators—1987

Appendix table 1-17. Percent of secondary-school mathematics teachers who have completed various courses, by grade level taught: 1985

Courses	Grade level taught	
	7-9	10-12
	— Percent —	
Education		
General methods of teaching	90	93
Methods of teaching secondary school mathematics	53	80
Methods of teaching middle school mathematics	37	25
Supervised student teaching	79	81
Psychology, human development	84	87
Institutional uses of computers	40	42
Mathematics/Computer science		
College algebra, trigonometry, elem. functions	80	87
Calculus	67	89
Advanced calculus	39	63
Differential equations	39	61
Geometry	67	80
Probability and statistics	59	76
Abstract algebra/number theory	48	69
Applications of mathematics/problem solving	34	39
History of mathematics	26	37
Other upper division mathematics	37	63
Computer programming	46	64

SOURCE: Research Triangle Institute, 1985 *National Survey of Science and Mathematics Education*
Science & Engineering Indicators—1987

Appendix table 1-18. Percent of secondary science and mathematics teachers who feel inadequately qualified to teach one or more of their courses: 1977 and 1985/86

Subject and grade level	1977	1985/86
	Percent	
Science		
Grades 7-9	13	7
Grades 10-12	13	7
Mathematics		
Grades 7-9	11	9
Grades 10-12	5	5

SOURCE: Research Triangle Institute, 1985 *National Survey of Science and Mathematics Education*

Science & Engineering Indicators—1987

Appendix table 1-19. Percent of elementary- and secondary-school science and mathematics teachers, by year in which they most recently took a college course in the subject they teach: 1985/86

Last course taken	Science			Mathematics		
	Grade level			Grade level		
	K-6	7-9	10-12	K-6	7-9	10-12
	Percent					
Prior to 1975	39	18	20	36	27	25
1975 to 1982	31	28	31	29	31	32
1983 or later	16	47	46	24	34	38
Unknown	13	7	3	10	8	5

SOURCE: Research Triangle Institute, 1985 *National Survey of Science and Mathematics Education*

Science & Engineering Indicators—1987

Appendix table 1-20. Percent of elementary- and secondary-school science and mathematics teachers, by time spent in in-service education during the last 12 months: 1985/86

Time spent in in-service education in the last 12 months	Science			Mathematics		
	Grade level taught			Grade level taught		
	K-6	7-9	10-12	K-6	7-9	10-12
	Percent					
None	52	31	28	41	31	35
Less than 6 hours	23	22	22	31	26	18
6-15 hours	13	23	25	16	22	21
16-35 hours	4	10	12	5	11	13
More than 35 hours	3	10	12	3	8	10
Unknown	5	2	1	5	3	2

SOURCE: Research Triangle Institute, 1985 *National Survey of Science and Mathematics Education*

Science & Engineering Indicators—1987

Appendix table 1-21. Supply of new teacher graduates, with alternative projections: 1970-92

Fall of year	Thousands		
1970	284		
1971	314		
1972	317		
1973	313		
1974	279		
1975	238		
1976	222		
1977	194		
1978	181		
1979	163		
1980	144		
1981	141		
1982	143		
1983	146		
Alternate Projections			
	Low	Intermediate	High
	Thousands		
1984	126	146	160
1985	121	146	163
1986	115	144	165
1987	110	142	168
1988	107	139	171
1989	105	139	176
1990	102	139	181
1991	100	138	184
1992	99	137	188

SOURCE: U.S. Department of Education, Center for Education Statistics, *The Condition of Education*, 1984 Edition (NCES 84-401), p. 36

See figure 1-9.

Science & Engineering Indicators—1987

Appendix table 1-22. Demand for new classroom teachers in elementary and secondary schools: 1970-92

Fall of year	Total	Elementary schools	Secondary schools
Thousands			
1970	208	115	93
1971	163	71	82
1972	179	107	72
1973	175	89	86
1974	183	103	80
1975	186	101	85
1976	150	78	72
1977	181	107	74
1978	138	82	56
1979	129	85	44
1980	127	69	58
1981	110	66	44
1982	143	94	49
1983	148	82	66
1984	142	78	64
1985	157	95	62
1986	170	114	56
1987	160	114	46
1988	164	126	38
1989	173	126	47
1990	183	131	52
1991	195	129	66
1992	209	129	80

Note: Data for 1970-82 are actual new hires. Data for 1983-92 are the intermediate value of three alternative projections (low, intermediate, and high).

SOURCE: U.S. Department of Education, Center for Education Statistics, *The Condition of Education*, 1984 Edition (NCES 84-401), p. 36

See figure 1-9.

Science & Engineering Indicators—1987

Appendix table 1-23. Actual and projected public school enrollment:¹ 1970-92

Fall of year	Thousands
1970	45,909
1971	46,081
1972	45,744
1973	45,429
1974	45,053
1975	44,791
1976	44,317
1977	43,577
1978	42,550
1979	41,645
1980	40,987
1981	40,099
1982	39,652
1983	39,352
1984	39,293
1985	39,513
1986 ²	39,712
1987 ²	39,916
1988 ²	40,116
1989 ²	40,379
1990 ²	40,898
1991 ²	41,548
1992 ²	42,259

¹ Includes most kindergarten and some nursery school enrollment.

² Estimated.

SOURCE: U.S. Department of Education, Center for Education Statistics, *Public and Private Elementary and Secondary Enrollments: Outlook to the Year 2000* (1987)

See figure 1-9.

Science & Engineering Indicators—1987

Appendix table 1-24. States which have enacted testing for initial certification of teachers: 1986

State	Enacted	Year effective	Test Used ¹
Alabama	1980	1981	State
Arizona	1980	1980	State
Arkansas	1979	1983	NTE
California	1981	1982	State
Colorado	1981	1983	CAT
Connecticut	1982	1985	State
Delaware	1982	1983	PPST
Florida	1978	1980	State
Georgia	1975	1980	State
Hawaii	1986	1986	NTE
Illinois	1985	1988	State
Indiana	1984	1985	NTE
Kansas	1984	1986	(²)
Kentucky	1984	1985	NTE
Louisiana	1977	1978	NTE
Maine	1984	1988	NTE
Massachusetts	1985	(²)	(²)
Mississippi	1975	1977	NTE
Missouri	1985	1988	(²)
Montana	1985	1986	(²)
Nebraska	1984	1989	(²)
New Hampshire	1984	1985	NTE
New Jersey	1984	1985	NTE
New Mexico	1981	1983	NTE
New York	1980	1984	NTE
North Carolina	1964	1964	NTE
Oklahoma	1980	1982	State
Oregon	1984	1985	CBEST
South Carolina	1979	1982	NTE and State
South Dakota	1985	1986	NTE
Tennessee	1980	1981	NTE
Texas	1981	1986	State
Virginia	1979	1980	NTE
Washington	1984	(²)	(²)
West Virginia	1982	1985	State

¹ Tests: CAT = California Achievement Test; CBEST = California Basic Educational Skills Test; NTE = National Teacher Exam; PPST = Pre-professional Skills Test; State = State developed test.

² To be determined.

SOURCE: Educational Commission of the States, *Cleanngghouse Notes*, November 1985

Science & Engineering Indicators—1987

Appendix table 1-25. State-required Carnegie units (1-year courses) for high school graduation for language arts, social studies, mathematics, and science: 1958-86

Year	Mathematics		Science	
	Mean units required	Number of states requiring	Mean units required	Number of states requiring
1958	1.1	31	1.2	31
1974	1.3	36	1.2	35
1980	1.3	35	1.2	35
1983	1.9	38	1.7	38
1984	2.1	44	1.9	44
1985	2.2	44	1.9	44
1986	2.3	45	1.9	45

Year	Language Arts		Social studies	
	Mean units required	Number of states requiring	Mean units required	Number of states requiring
1958	3.4	37	1.9	44
1974	3.4	40	2.0	45
1980	3.4	39	2.0	42
1983	3.6	41	2.1	44
1984	3.8	45	2.4	49
1985	3.8	45	2.4	49
1986	3.8	45	2.5	49

SOURCE: Education Commission of the States. Department of Research and Information, *Cleannghouse Notes*, various years.

See figure 1-14.

Science & Engineering Indicators—1987

Appendix table 1-26. State minimum competency testing for elementary and secondary school assessment purposes: 1985

States using minimum competency	Government level setting standards	Grade levels assessed	Test purposes					First graduating class assessed
			Grade promotion	High school graduation	Early exit	Remediation	Other	
Alabama	State	3,6,9,11		X		X	X	1985
Arizona	State/Local	8,12	(¹)	X				1976
Arkansas	State	3,4,6,8				X		
California	State/Local	4-11, 16 yr olds +		X	X	X	X	
Colorado	Local	9,12		Local Opt.				1979
Connecticut ²	State	4,6,8				X	X	
Delaware	State	1-8,11		X			X	1981
Florida	State/Local	3,5,8,11	X	X				1983
Georgia	State	K,1,3,6,8,10	(³)	X		X	X	1985
Hawaii ⁴	State	3,9-12		X		X	X	1983
Idaho	State	8-12				X	X	1982
Illinois	Local	Local Opt.					Local Opt.	
Indiana	Local	3,6,8,10				X	X	
Kansas ⁵	State	2,4,6,8,10					Local Opt.	
Kentucky ⁶		K-12	X	X		X		
Louisiana ⁷	State	2,3,4,5	X					
Maryland	State	7,9		X		X	X	1982
Massachusetts	Local	Local Opt.				X		
Michigan	State	4,7,10				X	Local Opt.	
Mississippi	State	3,5,8,11		X			X	1987 ⁸
Missouri	State	8 +				X	X	
Nebraska	Local	5 +					X	
Nevada	State	3,6,9,11		X		X		1982
New Hampshire ⁹	State	4,8,12	Local Opt.	Local Opt.			Local Opt.	
New Jersey	State	9-12		X		X	X	1985
New Mexico	State	10-12					X	1981
New York	State	3,5,6,8-12		X		X		1979
N. Carolina ¹⁰	State	3,6,8,10		X			X	1980
Ohio	Local	Local Opt. ¹¹				X	Local Opt.	1990
Oklahoma ¹²	None	3,6,9,12					X	
Oregon	Local	Local Opt.	X					1978
Pennsylvania	State	3,5,8				X		
S. Carolina ¹³	State	1,2,3,6,8,11	X	X		X	X	1990
Tennessee	State/Local	3,6,8,9-12	X	X		X		1982
Texas	State	1,3,5,7,9,11,12		X		X	X	1987
Utah	Local	Local Opt.				X	X	1988
Vermont	State	1-8					X	1981
Virginia	State/Local	K-6,10-12		X			X	
Wisconsin	Local	1-4,5,8,9-10		Local Opt.		X		
Wyoming	Local	Local Opt.				X		

¹ 1983 legislation calls for Arizona to develop a minimum course of study and criteria for high school graduation standards and for grade-to-grade promotion criteria. Local school districts are implementing standards.

² In Connecticut, a new program of State testing for Grade 4 began in 10/85 and will be expanded to Grades 6 and 8 in 10/86. The testing is the State Criterion-referenced Mastery program. The Grade 9 State proficiency test begun in 1980 will be administered for the final time in 1986.

³ Effective 8/25, third grade students must demonstrate acceptable performance on criterion-reference tests in mathematics and reading before promotion to the fourth grade. Beginning in 1988/9 school year, students must pass the school readiness test to be eligible for the first grade.

⁴ In Hawaii, students have three options: paper-pencil test, performance test, or course. Students must take a paper-pencil test the first time (Grade 9).

⁵ The Kansas Minimum Competency Assessment (MCA) was reestablished by 1984 legislative action (SB 473). The MCA will be in effect for 5 school years, 1984/5 through 1988/9.

⁶ Kentucky's 1984 legislation required the State Superintendent to recommend a process of using test results for promotion and graduation to the 1986 legislature.

⁷ Louisiana added Grade 8 beginning with the 1986/7 school year.

⁸ Although the first class assessed graduated in 1987, the first class required to pass for graduation will be the class of 1989.

⁹ New Hampshire requires students be tested in elementary, middle, and high school. Some local districts test in grades other than 4, 8, and 12.

(continued)

Appendix table 1-26. (Continued)

¹⁰ In North Carolina, grades 3, 6, and 8 are given an annual standardized achievement test. Local school districts use the results as a diagnostic tool.

¹¹ Locally based, competency-based education programs are given in the areas of English composition, math, and reading, including testing at least once in grades 1-4. Grades 5-8 and 9-11 shall be implemented later than 1989-90.

¹² Test was given in Oklahoma during the 1978-9 school year. There has been no followup to the program. However, a plan for statewide testing was submitted for legislative action in January 1985.

¹³ The South Carolina Education Improvement Act of 1984 specifies that the 11th grade test being used to gather base-line data be replaced in the 1985-6 school year with an exit exam in the 10th grade. All students graduating in 1990 and after must pass the exam.

Note: Some states have dates for first high school graduating class to be assessed with no expected use for high school graduation. American Samoa is currently developing a minimum competency testing program.

SOURCE: Educational Commission of the States, Department of Research and Information, "State Activity - Minimum Competency Testing," *Clearinghouse Notes*, November 1985.

Science & Engineering Indicators-1987

Appendix table 1-27. Mean percentage of items taught (opportunity-to-learn) to eighth grade students, by country and subject matter: 1981/2

Country	Arithmetic	Algebra	Geometry	Statistics	Measurement
	Percent				
Belgium (Flemish)	76	72	31	39	84
Canada (B.C.)	83	84	48	47	77
England/Wales	78	63	54	69	80
Finland	76	70	39	52	70
France	86	87	43	50	92
Hungary	91	91	86	86	97
Israel	71	79	46	52	63
Japan	85	83	51	76	95
Luxembourg	79	52	35	32	82
Netherlands	82	73	67	32	82
New Zealand	67	62	59	60	70
Nigeria	79	72	65	64	71
Canada (Ontario)	87	70	49	61	84
Sweden	66	45	35	47	67
Thailand	86	83	57	56	86
United States	87	69	44	73	72

SOURCE: International Association for the Evaluation of Educational Achievement, *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, University of Illinois (Stipes Publishing Company, January 1987).

Science & Engineering Indicators—1987

Appendix table 1-28. Mean percentage of items taught (opportunity-to-learn) to twelfth grade students, by country and subject matter: 1981/2

Country	Sets and relations	Number systems	Algebra	Geometry	Elementary functions and calculus	Probability and statistics
	Percent					
Belgium (Flemish)	91	80	92	82	88	46
Canada (B.C.)	65	75	82	50	32	29
England/Wales	48	74	86	69	85	87
Finland	88	90	92	79	87	87
Hungary	45	55	87	74	67	27
Israel	38	56	70	49	79	39
Japan	95	80	100	89	92	82
New Zealand	85	90	93	75	93	86
Canada (Ontario)	62	60	83	52	83	33
Sweden	60	87	90	66	85	75
Thailand	81	75	78	63	63	90
United States	83	83	88	62	54	45

SOURCE: International Association for the Evaluation of Educational Achievements, *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, University of Illinois (Stipes Publishing Company, January 1987).

Science & Engineering Indicators—1987

**Appendix table 1-29. Mean percentage score of eighth grade students
on the international mathematics achievement test,
by country and subject matter: 1981/2**

Country	Arithmetic	Algebra	Geometry	Statistics	Measurement
	Percent				
Belgium (Flemish)	58	53	43	58	58
Belgium (French)	57	49	43	52	57
Canada (B. C.)	58	48	42	61	52
England Wales	48	40	45	60	49
Finland	46	44	43	58	51
France	58	55	38	57	60
Hong Kong	55	43	43	56	53
Hungary	57	50	53	60	62
Israel	50	44	36	52	46
Japan	60	60	58	71	69
Luxembourg	45	31	25	37	50
Netherlands	59	51	52	66	62
New Zealand	46	39	45	57	45
Nigeria	41	32	26	37	31
Canada (Ontario)	55	42	43	57	51
Scotland	50	43	46	59	48
Swaziland	32	25	31	36	35
Sweden	41	32	39	56	49
Thailand	43	38	39	45	48
United States	51	43	38	57	42

SOURCE: International Association for the Evaluation of Educational Achievements, *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, University of Illinois (Stipes Publishing Company, January 1987)

Science & Engineering Indicators—1987

**Appendix table 1-30. Mean percentage score of twelfth grade students on the international mathematics
achievement test, by country and subject matter: 1981/2**

Country	Sets and relations	Number systems	Algebra	Geometry	Elementary functions and calculus	Probability and statistics
	Percent					
Belgium (Flemish)	72	48	61	42	46	43
Belgium (French)	66	44	55	38	43	42
Canada (B. C)	48	43	47	30	21	38
England Wales	61	59	66	51	58	64
Finland	77	57	69	48	55	58
Hong Kong	80	78	78	65	71	73
Hungary	35	28	45	30	26	29
Israel	51	46	60	35	45	38
Japan	79	68	78	60	66	70
New Zealand	72	51	57	43	48	58
Canada (Ontario)	69	47	57	42	46	46
Scotland	50	39	48	42	32	46
Sweden	59	62	60	49	51	64
Thailand	52	33	38	28	26	34
United States	56	40	43	31	29	40

SOURCES: International Association for the Evaluation of Educational Achievement, *The Underachieving Curriculum: Assessing U.S. School Mathematics from an International Perspective*, University of Illinois (Stipes Publishing Company, January 1987)

Science & Engineering Indicators—1987

Appendix table 1-31. Average percent new content in three mathematics text series — comparison of the first 200 pages and the remainder of the book

	Grade level								
	1	2	3	4	5	6	7	8	9
	Percent								
First 200 pages	70	28	52	31	37	26	27	19	77
Remainder of book	80	63	79	61	61	53	44	40	95

SOURCE: Glanders, Jim, "How Much of the Content in Mathematics Textbooks is New?", University of Chicago (Unpublished report, November 13, 1986)

See figure 1-17.

Science & Engineering Indicators—1987

Appendix table 1-32. Attitudes of eighth and twelfth grade mathematics students towards mathematics in their personal lives: 1981/2

	8th Grade	12th Grade
	— Percent giving a high rating —	
I usually understand what we are talking about in class	71	75
I really want to do well in mathematics	87	91
I feel good when I solve a mathematics problem by myself	78	91
My parents really do want me to do well in mathematics ¹	86	89
It does not scare me to have to take mathematics	71	81
Mathematics is easier for me than for most persons ¹	56	76
If I had a choice, I would learn more mathematics ¹	66	76
Mathematics helps me think logically	64	85
There is usually a rule to follow in mathematics	82	67

¹ Reworded to capture the positive intent of the question.

SOURCE: Travers, K. J., *Second Study of Mathematics, Detailed National Report — United States*, December, 1986, pp. 382-384

Science & Engineering Indicators—1987

Appendix table 1-33. Attitudes of eighth grade U.S. students towards mathematics: 1981/2

	Percent giving a high rating to:		
	Importance	Ease	Likes
Memorizing	84	36	22
Measures	83	52	43
Checking	79	72	25
Equations	78	53	44
Decimals	76	56	44
Estimating	68	68	49
Charts and graphs	67	74	57
Ratios and proportions	67	45	35
Word problems	66	39	28
Tables	61	49	37
Geometric figures	60	45	38
Calculators	54	86	75
Inequalities	50	35	25
Sets	47	57	38
Drawing figures	46	55	42
All subtopics	66	55	40

Note: Attitudes were obtained at the end of the school year, after exposure to these topics.

SOURCE: Travers, K. J., *Second Study in Mathematics, Detailed National Report — United States*, December, 1986, pp. 367-369

Science & Engineering Indicators—1987

Appendix table 1-34. Attitudes of twelfth grade U.S. students towards mathematics: 1981/2

	Percent giving a high rating to:		
	Importance	Ease	Likes
Equations	94	71	71
Checking	90	78	29
Memorizing	85	46	18
Calculators	80	95	85
Word problems	78	26	29
Function graphs	69	64	37
Probability	66	34	37
Charts and graphs	62	80	42
Complex numbers	62	52	37
Derivatives	56	37	34
Limits	55	42	30
Sequences and series	53	43	33
Proofs	52	20	18
Vectors	48	41	30
Integrals	46	26	25
All subtopics	66	50	37

Note: Attitudes were obtained at the end of the school year, after exposure to these topics.

SOURCE: Travers, K. J., *Second Study in Mathematics, Detailed National Report — United States*, December, 1986, pp. 371-373

Science & Engineering Indicators—1987

Appendix table 2-1. U.S. population and college enrollment of 18-21 year olds, by selected race and gender, 1970-85

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
	—Thousands—															
Total male population	6,000	6,389	6,882	7,080	7,350	7,584	7,729	7,823	7,886	7,941	7,922	8,052	7,917	7,796	7,554	7,260
Total male enrollment	2,429	2,534	2,536	2,423	2,468	2,682	2,600	2,676	2,593	2,533	2,615	2,689	2,722	2,650	2,710	2,662
Percent	40.5	39.7	36.8	34.2	33.6	35.4	33.6	34.2	32.9	31.9	33.0	33.4	34.4	34.0	35.9	36.7
Total female population	7,076	7,250	7,535	7,683	7,943	8,109	8,230	8,318	8,359	8,373	8,350	8,428	8,276	8,062	7,833	7,623
Total female enrollment	2,022	2,187	2,260	2,178	2,321	2,575	2,735	2,668	2,603	2,664	2,743	2,899	2,896	2,785	2,754	2,862
Percent	28.6	30.2	30.0	28.3	29.2	31.8	33.2	32.1	31.1	31.8	32.9	34.4	35.0	34.5	35.2	37.5
White male population	5,194	5,531	5,973	6,129	6,373	6,545	6,651	6,730	6,783	6,827	6,793	6,820	6,626	6,501	6,289	6,069
White male enrollment	2,246	2,292	2,304	2,194	2,210	2,417	2,317	2,396	2,275	2,250	2,346	2,363	2,377	2,346	2,367	2,313
Percent	43.2	41.4	38.6	35.8	34.7	36.9	34.8	35.6	33.5	33.0	34.5	34.6	35.9	36.1	37.6	38.1
White female population	6,099	6,238	6,481	6,573	6,784	6,903	6,991	7,051	7,073	7,072	7,033	7,051	6,895	6,689	6,461	6,280
White female enrollment	1,799	1,951	2,024	1,952	2,039	2,238	2,368	2,282	2,251	2,327	2,363	2,514	2,519	2,412	2,380	2,483
Percent	29.5	31.3	31.2	29.7	30.1	32.4	33.9	32.4	31.8	32.9	33.6	35.7	36.5	36.1	36.8	39.5
Black male population	746	779	825	854	865	941	957	946	951	956	967	1,032	1,058	1,059	1,040	1,017
Black male enrollment	154	200	193	189	202	218	234	205	220	220	199	225	216	205	241	261
Percent	20.6	25.7	23.4	22.1	23.4	23.2	24.5	21.7	23.1	23.0	20.6	21.8	20.4	19.4	23.2	25.7
Black female population	896	932	980	998	1,031	1,085	1,110	1,130	1,132	1,137	1,148	1,193	1,194	1,177	1,167	1,132
Black female enrollment	189	202	204	168	222	280	320	326	288	283	309	312	300	295	298	272
Percent	21.1	21.7	20.8	16.8	21.5	25.8	28.8	28.8	25.4	24.9	26.9	26.2	25.1	25.1	25.5	24.0
Hispanic male population	NA	NA	372	355	428	416	458	462	439	486	589	611	559	577	508	551
Hispanic male enrollment	NA	NA	83	76	99	105	108	99	83	110	120	125	99	102	105	97
Percent	NA	NA	22.3	21.4	23.1	25.2	23.6	21.4	18.9	22.6	20.4	20.5	17.7	17.7	20.7	17.6
Hispanic female population	NA	NA	419	382	466	484	507	519	521	525	578	642	561	610	579	594
Hispanic female enrollment	NA	NA	68	77	107	114	119	120	94	110	110	127	148	157	164	157
Percent	NA	NA	16.2	20.2	23.0	23.6	23.5	23.1	18.0	21.0	19.0	19.8	26.4	25.7	28.3	26.4

Note: NA = Not Available.

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Current Population Report* (Series P-20), various issues

See figure O-18 in Overview.

Science & Engineering Indicators—1987

Appendix table 2-2. S E graduate enrollments of U.S. citizens in all institutions, by field, race, and enrollment status: 1980-86

	Full-time						Part-time					
	1980	1982	1983	1984	1985	1986	1980	1982	1983	1984	1985	1986
Total science and engineering	198,429	197,374	200,906	202,699	201,153	203,559	NA	133,190	138,088	146,775	152,173	154,120
White	149,481	159,171	168,044	167,013	163,139	165,975	79,174	102,410	108,791	111,203	114,648	116,179
Black	6,607	7,225	7,469	7,632	7,272	7,275	5,020	6,100	6,999	7,238	7,295	7,119
Hispanic	4,922	5,496	6,486	6,873	6,723	7,066	2,490	3,830	4,683	5,189	4,692	4,485
Asian	5,394	5,657	6,457	7,482	8,314	9,291	2,830	3,678	4,200	4,845	5,850	5,893
Other U.S. citizens	32,025	19,825	12,450	13,699	15,705	13,952	NA	17,172	13,415	18,300	19,688	20,444
Foreign	50,730	57,923	62,784	64,622	69,201	75,676	NA	10,495	11,577	12,304	12,096	12,747
Total sciences	173,321	168,558	168,759	169,733	168,086	169,140	NA	102,621	104,915	111,445	114,628	115,694
White	130,878	137,494	142,848	141,266	137,755	139,092	60,803	80,711	84,005	84,415	87,607	88,484
Black	6,135	6,706	6,803	6,920	6,547	6,490	4,562	5,475	6,246	6,407	6,511	6,344
Hispanic	4,350	4,895	5,701	6,095	5,941	6,190	1,978	3,330	3,973	4,310	3,879	3,678
Asian	3,888	4,238	4,698	5,268	5,671	6,392	1,626	2,350	2,497	2,842	3,355	3,354
Other U.S. citizens	28,070	15,225	8,709	10,184	12,172	10,976	NA	10,755	8,194	13,471	13,276	13,834
Foreign	32,731	36,500	39,738	41,006	44,779	48,363	NA	6,709	6,788	7,395	7,188	7,611
Physical sciences	17,174	17,555	17,981	18,271	18,150	18,369	NA	3,699	3,832	4,150	4,106	4,444
White	13,919	14,742	15,478	15,423	15,186	15,338	2,404	2,947	3,185	3,415	3,293	3,463
Black	323	418	412	440	385	400	96	135	163	173	163	165
Hispanic	305	387	449	461	526	556	65	109	114	80	78	98
Asian	513	532	590	759	789	863	113	165	159	183	183	201
Other U.S. citizens	2,114	1,476	1,052	1,188	1,264	1,212	NA	343	211	299	389	517
Foreign	5,744	6,485	7,232	7,603	8,472	9,329	NA	460	430	464	467	569
Environmental sciences	9,570	9,789	10,391	10,125	9,693	9,452	NA	3,501	3,343	3,870	4,139	3,868
White	7,523	8,388	9,348	8,726	8,445	8,406	2,230	3,005	3,023	3,416	3,458	3,257
Black	66	76	83	86	85	66	38	27	29	26	42	36
Hispanic	115	132	146	198	198	206	34	59	81	74	74	65
Asian	143	136	158	149	155	143	27	72	85	45	38	34
Other U.S. citizens	1,723	1,057	656	966	810	631	NA	338	125	309	527	476
Foreign	1,399	1,647	1,698	1,590	1,697	1,813	NA	237	177	218	212	209
Mathematical sciences	6,648	6,935	6,726	6,840	7,079	7,263	NA	5,733	5,756	5,708	5,597	5,208
White	5,042	5,571	5,589	5,592	5,675	5,846	3,034	4,587	4,742	4,424	4,196	3,629
Black	141	174	164	185	199	242	159	183	240	215	224	206
Hispanic	140	174	205	185	163	182	50	116	127	113	104	123
Asian	205	298	337	324	435	469	119	194	227	310	257	258
Other U.S. citizens	1,120	718	431	554	607	524	NA	653	420	646	816	992
Foreign	3,254	3,888	4,245	4,592	4,884	5,193	NA	643	716	691	546	715
Computer sciences	4,521	5,981	6,724	6,905	8,463	9,100	NA	9,458	11,344	12,230	13,684	13,772
White	2,793	4,339	5,053	5,209	5,815	6,482	3,758	7,235	8,429	8,430	9,247	9,308
Black	67	198	207	193	188	276	126	330	357	335	390	383
Hispanic	42	105	105	111	128	170	58	144	177	149	283	255
Asian	200	365	558	534	741	895	369	525	541	616	1,059	1,144
Other U.S. citizens	1,419	974	801	858	1,591	1,277	NA	1,224	1,840	2,700	2,705	2,682
Foreign	2,066	3,190	3,963	4,423	5,465	5,971	NA	1,183	1,585	1,806	1,910	1,883
Life sciences	63,543	60,522	59,690	59,580	58,790	58,344	NA	31,106	32,159	33,638	34,927	35,755
White	50,716	51,880	52,517	52,171	50,217	50,196	20,476	26,344	27,441	28,154	28,567	29,224
Black	1,633	1,697	1,730	1,735	1,829	1,731	1,078	1,244	1,526	1,679	1,744	1,620
Hispanic	1,451	1,338	1,776	1,816	2,091	2,056	521	603	811	810	949	856
Asian	1,644	1,622	1,691	1,871	2,021	2,250	457	603	679	729	817	824
Other U.S. citizens	8,099	3,985	1,976	1,987	2,632	2,111	NA	2,312	1,702	2,266	2,850	3,231
Foreign	8,866	9,732	10,421	10,762	11,387	12,585	NA	1,529	1,432	1,569	1,549	1,643
Psychology	25,482	24,739	25,657	25,974	25,429	25,871	NA	13,965	14,015	16,868	17,032	16,468
White	17,612	19,198	21,369	20,769	20,710	21,133	7,124	11,123	11,333	12,460	13,354	12,954
Black	1,017	1,021	1,145	1,172	1,116	1,142	401	622	771	1,026	959	905
Hispanic	971	1,032	1,146	1,391	1,038	1,193	327	439	684	1,204	712	676
Asian	302	319	368	463	423	510	70	122	164	236	260	240
Other U.S. citizens	5,580	3,169	1,629	2,179	2,142	1,893	NA	1,659	1,063	1,942	1,747	1,693
Foreign	1,210	1,079	1,092	1,089	1,228	1,215	NA	315	340	374	372	350
Social sciences	46,383	43,037	41,590	42,039	40,482	40,742	NA	35,159	34,466	34,982	35,144	36,178
White	33,273	33,376	33,494	33,377	31,707	31,691	21,777	25,470	25,852	25,117	25,494	26,649
Black	2,888	3,122	3,062	3,107	2,746	2,634	2,664	2,934	3,160	2,951	2,989	3,030
Hispanic	1,326	1,727	1,874	1,932	1,797	1,828	923	1,860	1,979	1,880	1,680	1,605
Asian	881	966	996	1,167	1,108	1,263	471	669	642	723	740	652
Other U.S. citizens	8,015	3,846	2,164	2,456	3,124	3,326	NA	4,226	2,833	4,311	4,241	4,242
Foreign	10,192	10,479	11,087	10,948	11,647	12,257	NA	2,342	2,108	2,273	2,131	2,243
Total engineering	25,108	28,816	32,147	32,965	33,066	34,418	NA	30,569	33,173	35,330	37,545	38,426
White	18,603	21,677	25,196	25,747	25,384	26,884	18,371	21,699	24,786	25,788	27,041	27,695
Black	472	519	666	712	724	784	458	625	753	832	784	775
Hispanic	572	601	785	778	782	877	512	500	710	879	813	807
Asian	1,506	1,419	1,759	2,214	2,643	2,899	1,204	1,328	1,703	2,003	2,496	2,540
Other U.S. citizens	3,955	4,600	3,741	3,514	3,533	2,974	NA	6,417	5,221	5,828	6,411	6,609
Foreign	17,999	21,423	23,046	23,616	24,421	27,314	NA	3,786	4,789	4,909	4,908	5,136

Note: NA = Not Available

SOURCE: National Science Foundation, *Academic Science Engineering Graduate Enrollment and Support*, Fall 1986 (forthcoming)
See figure 2-2.

Science & Engineering Indicators—1987

**Appendix table 2-3. S/E enrollment of U.S. citizens in doctorate-granting institutions by field, race, and enrollment status:
1980-86**

Field and race	Full-time							Part-time						
	1980	1981	1982	1983	1984	1985	1986	1980	1981	1982	1983	1984	1985	1986
Total science and engineering	181,864	181,593	181,637	183,642	185,283	184,753	187,171	NA	NA	101,311	104,834	106,299	111,067	113,710
White	140,799	133,217	148,143	155,420	155,634	153,257	156,317	63,728	62,124	79,692	84,039	83,836	87,502	90,401
Black	5,595	5,402	5,992	5,996	5,938	5,956	5,973	3,747	3,546	4,315	4,844	4,641	4,533	4,558
Hispanic	4,535	4,117	5,024	5,746	5,853	6,066	6,431	1,910	2,183	2,981	3,464	3,346	3,251	3,367
Asian	5,073	4,590	5,224	5,843	6,658	7,509	8,500	2,246	2,269	2,808	2,989	3,057	3,967	4,120
Total sciences	157,428	155,977	153,762	152,532	153,321	152,550	153,873	NA	NA	75,058	76,138	76,968	79,780	81,030
White	122,458	115,178	126,991	130,896	130,465	128,308	130,059	46,705	44,859	60,804	62,504	62,237	64,689	66,014
Black	5,159	5,008	5,519	5,386	5,279	5,295	5,246	3,349	3,159	3,804	4,245	3,979	3,944	3,957
Hispanic	3,973	3,638	4,454	5,002	5,124	5,339	5,579	1,482	1,793	2,557	2,877	2,661	2,624	2,652
Asian	3,589	3,522	3,902	4,206	4,582	5,010	5,751	1,229	1,325	1,721	1,750	1,787	2,151	2,165
Physical sciences	16,668	16,523	17,038	17,451	17,720	17,700	17,922	NA	NA	2,822	2,907	2,900	2,987	3,100
White	13,638	13,260	14,415	15,138	15,119	14,926	15,097	1,924	1,904	2,319	2,486	2,514	2,440	2,617
Black	262	274	339	330	363	301	314	70	71	95	97	93	87	86
Hispanic	288	315	375	434	444	514	531	49	40	86	105	63	50	56
Asian	495	452	502	538	683	742	835	81	113	126	103	104	95	88
Environmental sciences	8,930	9,026	9,269	9,805	9,730	9,277	9,111	NA	NA	2,674	2,652	2,855	3,154	2,969
White	7,170	6,849	7,999	8,881	8,403	8,108	8,139	1,787	1,661	2,383	2,446	2,580	2,818	2,723
Black	54	59	59	77	79	82	62	18	20	16	22	22	29	28
Hispanic	111	125	112	136	184	160	180	22	21	44	65	59	33	37
Asian	135	100	130	145	133	147	137	18	15	48	63	24	20	9
Mathematical sciences	6,213	6,159	6,453	6,232	6,266	6,516	6,805	NA	NA	4,078	4,025	3,910	3,661	3,370
White	4,852	4,599	5,227	5,223	5,226	5,325	5,587	2,490	2,564	3,286	3,361	3,193	3,012	2,611
Black	106	119	146	126	134	162	191	114	120	122	147	121	105	110
Hispanic	125	157	163	201	168	161	168	31	46	81	94	82	70	80
Asian	197	231	278	285	246	352	416	95	89	126	141	175	145	155
Computer sciences	4,030	4,260	5,137	5,755	6,109	7,529	8,065	NA	NA	6,817	7,787	8,721	9,863	10,377
White	2,513	3,161	3,850	4,415	4,736	5,557	6,182	3,090	3,250	5,375	5,781	6,153	7,180	7,459
Black	38	70	116	117	128	154	228	79	119	233	253	249	303	282
Hispanic	30	37	86	83	97	106	152	38	36	90	111	111	229	211
Asian	142	199	279	442	453	597	727	253	306	366	363	437	778	818
Life sciences	59,226	58,183	56,343	55,139	55,890	55,112	55,054	NA	NA	23,800	24,873	25,300	25,990	27,380
White	48,155	45,304	48,644	48,869	49,474	47,680	47,801	15,902	15,540	20,723	21,657	21,981	22,048	23,362
Black	1,346	1,203	1,399	1,367	1,377	1,457	1,441	765	680	861	1,045	1,115	1,119	1,112
Hispanic	1,357	855	1,236	1,604	1,657	1,908	1,916	368	307	433	576	529	576	645
Asian	1,545	1,321	1,559	1,603	1,756	1,831	2,127	381	312	475	522	474	510	529
Psychology	20,526	20,712	20,216	20,403	20,653	20,476	20,993	NA	NA	7,759	7,488	8,135	8,784	8,491
White	14,764	13,062	15,574	17,311	17,255	17,242	17,659	4,233	3,991	6,361	6,146	6,337	6,897	6,762
Black	830	788	802	862	863	825	835	194	263	329	406	449	373	361
Hispanic	846	871	936	897	938	917	1,037	199	187	304	370	421	462	423
Asian	247	291	274	289	321	341	389	41	43	78	84	89	99	99
Social sciences	41,835	41,114	39,306	37,747	36,953	35,940	35,923	NA	NA	27,108	26,406	25,147	25,341	25,343
White	31,366	28,943	31,282	31,059	30,252	29,470	29,594	17,279	15,949	20,357	20,627	19,479	20,294	20,480
Black	2,523	2,495	2,658	2,507	2,335	2,314	2,175	2,109	1,886	2,148	2,275	1,930	1,928	1,978
Hispanic	1,216	1,278	1,546	1,647	1,636	1,573	1,595	775	1,156	1,519	1,556	1,396	1,204	1,200
Asian	828	928	880	904	990	1,000	1,120	360	447	502	474	484	504	467
Total engineering	24,436	25,616	27,875	31,110	31,962	32,203	33,298	NA	NA	26,253	28,696	29,331	31,287	32,680
White	18,341	18,039	21,152	24,524	25,169	24,949	26,258	17,023	17,265	18,888	21,535	21,599	22,813	24,387
Black	436	394	473	610	659	661	727	398	387	511	599	662	589	601
Hispanic	562	479	570	744	729	727	852	428	390	424	587	685	627	715
Asian	1,484	1,068	1,322	1,637	2,076	2,499	2,749	1,017	944	1,087	1,239	1,270	1,816	1,955

SOURCE: National Science Foundation, *Academic Science Engineering: Graduate Enrollment Fall 1986* (forthcoming), unpublished data

Appendix table 2-4. Full-time S/E graduate students in doctorate-granting institutions, by field and citizenship: 1980-86

Field and citizenship	1980	1981	1982	1983	1984	1985	1986
Total science and engineering	230,535	234,194	236,939	243,540	246,718	251,147	259,980
Foreign	48,671	52,601	55,302	59,898	61,435	66,394	72,809
Total sciences	188,596	189,377	188,252	190,024	191,961	195,207	200,055
Foreign	31,168	33,400	34,490	37,492	38,640	42,657	46,182
Physical sciences	22,254	22,600	23,330	24,492	25,149	25,967	27,074
Foreign	5,586	6,077	6,292	7,041	7,429	8,267	9,152
Environmental sciences	10,265	10,491	10,873	11,466	11,283	10,918	10,909
Foreign	1,335	1,465	1,604	1,661	1,553	1,641	1,798
Mathematical sciences	9,368	9,680	10,174	10,312	10,613	11,168	11,767
Foreign	3,155	3,521	3,721	4,080	4,347	4,652	4,962
Computer sciences	5,900	6,465	7,908	9,267	10,108	12,433	13,504
Foreign	1,870	2,205	2,771	3,512	3,999	4,904	5,439
Life sciences	67,711	67,195	65,653	65,098	66,044	66,112	67,205
Foreign	8,485	9,012	9,310	9,959	10,154	11,000	12,151
Psychology	21,580	21,544	21,103	21,309	21,578	21,524	22,007
Foreign	1,054	832	887	906	925	1,048	1,014
Social sciences	51,518	51,402	49,211	48,080	47,186	47,085	47,589
Foreign	9,683	10,288	9,905	10,333	10,233	11,145	11,666
Total engineering	41,939	44,817	48,687	53,516	54,757	55,940	59,925
Foreign	17,503	19,201	20,812	22,406	22,795	23,737	26,627

SOURCE: National Science Foundation, *Academic Science Engineering: Graduate Enrollment and Support, Fall 1986* (forthcoming)

See figure O-20 in Overview.

Science & Engineering Indicators—1987

**Appendix table 2-5. S/E graduate students in doctorate and master's granting institutions, by field and enrollment status:
1980-86**

Field and enrollment	1980		1981		1982		1983		1984		1985		1986	
	FT	PT	FT	PT	FT	PT	FT	PT	FT	PT	FT	PT	FT	PT
Total science and engineering	249,159	133,941	252,997	138,643	255,297	143,685	263,690	149,665	267,320	159,079	270,353	164,269	279,235	166,867
Doctorate-granting	230,535	103,134	234,194	105,774	236,939	109,857	243,540	104,523	246,718	116,350	251,147	120,875	259,980	124,223
Master's granting	18,624	30,807	18,803	32,869	18,358	33,828	20,150	35,142	20,602	42,729	19,206	43,394	19,255	42,644
Total sciences	206,052	101,964	206,740	104,421	205,058	109,330	208,497	11,703	210,739	118,840	212,865	121,816	217,503	123,305
Doctorate-granting	188,596	74,930	189,377	76,218	188,252	80,366	190,024	81,628	191,961	82,835	195,207	85,431	200,055	87,116
Master's granting	17,456	27,034	17,363	28,203	16,806	28,964	18,473	30,075	18,778	36,005	17,658	36,385	17,448	36,189
Physical sciences	22,918	4,034	23,308	4,074	24,040	4,159	25,213	4,262	25,874	4,613	26,622	4,573	27,697	5,013
Doctorate-granting	22,254	3,139	22,600	3,180	23,330	3,169	24,492	3,235	25,149	3,264	25,967	3,348	27,074	3,528
Master's granting	664	895	708	894	710	990	721	1,027	725	1,349	655	1,225	623	1,485
Environmental sciences	10,969	3,239	11,038	3,384	11,436	3,738	12,089	3,520	11,714	4,088	11,390	4,351	11,265	4,077
Doctorate-granting	10,265	2,530	10,491	2,572	10,873	2,884	11,466	2,801	11,283	3,043	10,918	3,334	10,909	3,156
Master's granting	704	709	547	812	563	854	623	719	431	1,045	472	1,017	356	921
Mathematical sciences	9,902	5,458	10,154	5,761	10,823	6,376	10,971	6,472	11,432	6,400	11,963	6,144	12,456	5,923
Doctorate-granting	9,368	4,257	9,680	4,324	10,174	4,584	10,312	4,560	10,613	4,454	11,168	4,100	11,767	3,911
Master's granting	534	1,201	474	1,437	649	1,792	659	1,912	819	1,946	795	2,044	689	2,012
Computer sciences	6,587	6,991	7,445	8,992	9,171	10,641	10,687	12,929	11,328	14,036	13,928	15,594	15,071	15,655
Doctorate-granting	5,900	5,484	6,465	6,676	7,908	7,668	9,267	9,028	10,108	10,258	12,433	11,390	13,504	11,848
Master's granting	687	1,507	980	2,316	1,263	2,973	1,420	3,901	1,220	3,778	1,495	4,204	1,567	3,807
Life sciences	72,409	30,095	72,241	30,883	70,254	32,635	70,111	33,591	70,341	35,207	70,177	36,477	70,929	37,398
Doctorate-granting	67,711	22,949	67,195	23,713	65,653	25,050	65,098	26,032	66,044	26,372	66,112	27,177	67,205	28,713
Master's granting	4,698	7,146	5,046	7,170	4,601	7,585	5,013	7,559	4,297	8,835	4,065	9,300	3,724	8,685
Psychology	26,692	13,944	26,725	13,966	25,818	14,280	26,749	14,355	27,063	17,242	26,657	17,404	27,085	16,818
Doctorate-granting	21,580	7,804	21,544	7,508	21,103	7,979	21,309	7,739	21,578	8,413	21,524	9,036	22,007	8,752
Master's granting	5,112	6,140	5,181	6,458	4,715	6,301	5,440	6,616	5,485	8,829	5,133	8,368	5,078	8,066
Social sciences	56,575	38,203	55,829	37,361	53,516	37,501	52,677	36,574	52,987	37,255	52,130	37,275	52,999	38,421
Doctorate-granting	51,518	28,767	51,402	28,245	49,211	29,032	48,080	28,233	47,186	27,031	47,085	27,046	47,589	27,208
Master's granting	5,057	9,436	4,427	9,116	4,305	8,469	4,597	8,341	5,801	10,224	5,045	10,229	5,410	11,213
Total engineering	43,107	31,977	46,257	34,222	50,239	34,355	55,193	37,962	56,581	40,239	57,488	42,453	61,732	43,562
Doctorate-granting	41,939	28,204	44,817	29,556	48,687	29,491	53,516	32,895	54,757	33,515	55,940	35,444	59,925	37,107
Master's granting	1,168	3,773	1,440	4,666	1,552	4,864	1,677	5,067	1,824	6,724	1,548	7,009	1,807	6,455

SOURCE: National Science Foundation, *Academic Science Engineering: Graduate Enrollment and Support, Fall 1986* (forthcoming)

Science & Engineering Indicators—1987

Appendix table 2-6. S/E postdoctorates in doctorate-granting institutions by field: 1980-86

Field	1980	1981	1982	1983	1984	1985	1986	Average annual Percent change	
								1985-86	1980-86
								Percent—	
Total sciences and engineering	18,411	19,646	19,366	20,761	21,587	22,598	24,136	6.8	4.6
Total sciences	17,433	18,606	18,388	19,659	20,392	21,249	22,716	6.9	4.5
Physical sciences	4,264	4,462	4,281	4,444	4,386	4,517	4,813	6.6	2.0
Environmental sciences	308	339	335	415	488	375	418	11.5	5.2
Mathematical sciences	162	133	194	170	203	226	201	11.1	3.7
Computer sciences	43	34	46	82	63	74	74	0.0	9.5
Life sciences	11,743	12,855	12,725	13,756	14,473	15,191	16,328	7.5	5.6
Psychology	475	471	520	435	422	498	526	5.6	1.7
Social sciences	438	332	287	357	357	368	356	3.3	3.4
Total engineering	978	1,040	978	1,102	1,195	1,349	1,420	5.3	6.4

SOURCE: National Science Foundation, *Academic Science Engineering Graduate Enrollment and Support: Fall 1986* (forthcoming)

See figures 2-1 and 2-20.

Science & Engineering Indicators—1987

Appendix table 2-7. S/E graduate students in all institutions, by gender: 1980-86

Field	1980	1981	1982	1983	1984	1985	1986	Average annual percent change	
								1985-86	1980-86
								Percent—	
Total sciences and engineering	383,100	391,640	398,982	413,355	426,399	434,622	446,102	2.6	2.6
Male	249,328	249,471	252,179	259,961	265,711	270,958	277,337	2.4	1.8
Female	133,772	142,169	146,803	153,394	160,688	163,664	168,765	3.1	3.9
Total sciences	308,016	311,161	314,388	320,200	329,579	334,681	340,808	1.8	1.7
Male	180,747	176,923	176,558	177,168	180,042	182,997	185,277	1.2	0.4
Female	127,269	134,238	137,830	143,032	149,537	151,684	155,531	2.5	3.4
Physical sciences	26,952	27,382	28,199	29,475	30,487	31,194	32,710	4.9	3.3
Male	22,352	22,366	22,776	23,594	24,201	24,636	25,712	4.4	2.4
Female	4,600	5,016	5,423	5,881	6,285	6,559	6,998	6.7	7.2
Environmental sciences	14,208	14,422	15,174	15,609	15,803	15,741	15,342	-2.5	1.3
Male	10,940	10,945	11,393	11,634	11,849	11,724	11,328	-3.4	0.6
Female	3,268	3,477	3,781	3,975	3,954	4,017	4,014	-0.1	3.5
Mathematical sciences	15,360	15,915	17,199	17,443	17,831	18,106	18,379	1.5	3.0
Male	11,272	11,419	12,109	12,222	12,562	12,574	12,795	1.8	2.1
Female	4,088	4,496	5,090	5,221	5,269	5,532	5,584	0.9	5.3
Computer sciences	13,578	16,437	19,812	23,616	25,364	29,522	30,726	4.1	14.6
Male	10,491	12,228	14,366	16,968	18,659	22,326	23,266	4.2	14.2
Female	3,087	4,209	5,446	6,648	6,705	7,196	7,460	3.7	15.8
Life sciences	102,504	103,124	102,889	103,702	105,548	106,653	108,328	1.6	0.9
Male	51,062	49,353	47,646	46,754	46,759	46,734	47,043	0.7	-1.4
Female	51,442	53,771	55,243	56,948	58,788	59,919	61,285	2.3	3.0
Psychology	40,636	40,691	40,098	41,104	44,305	44,060	43,903	-0.4	1.3
Male	19,036	17,902	16,980	16,706	17,170	16,609	16,088	-3.1	-2.8
Female	21,600	22,789	23,118	24,398	27,135	27,452	27,815	1.3	4.3
Social sciences	94,778	93,190	91,017	89,251	90,242	89,405	91,420	2.3	-0.6
Male	55,594	52,710	51,288	49,290	48,842	48,396	49,045	1.3	-2.1
Female	39,184	40,480	39,729	39,961	41,400	41,009	42,375	3.3	1.3
Total engineering	75,084	80,479	84,594	93,155	96,820	99,941	105,294	5.4	5.8
Male	68,581	72,548	75,621	82,793	85,669	87,961	92,060	4.7	5.0
Female	6,503	7,931	8,973	10,362	11,151	11,980	13,234	10.5	12.6

SOURCE: National Science Foundation, *Academic Science Engineering Graduate Enrollment and Support: Fall 1986* (forthcoming)

See figure 2-1.

Science & Engineering Indicators—1987

Appendix table 2-8. Region of origin of foreign students in the United States: 1974/75 to 1985/86

Academic year	Total ¹	Africa	Europe	Latin America	Middle East	North America	Oceania	South and East Asia
1974/75	154,580	18,400	13,740	26,270	23,910	8,630	2,650	58,460
1975/76	179,340	25,290	14,400	29,820	32,590	9,720	2,740	64,540
1976/77	203,070	25,860	16,700	37,240	38,490	11,420	3,150	70,020
1977/78	235,510	29,560	19,310	38,840	57,210	12,920	3,810	73,760
1978/79	263,940	33,990	21,690	41,120	70,430	15,520	4,150	76,850
1979/80	286,340	36,180	22,570	42,280	83,700	15,570	4,140	81,730
1980/81	311,880	38,180	25,330	49,810	84,710	14,790	4,180	94,640
1981/82	326,300	41,660	28,990	55,360	74,390	15,460	4,000	106,160
1982/83	336,990	42,690	31,570	56,810	67,280	14,570	4,040	119,650
1983/84	338,890	41,690	31,860	52,350	60,660	15,670	4,090	132,270
1984/85	342,110	39,520	33,350	48,560	56,580	15,960	4,190	143,680
1985/86	343,777	34,190	34,310	45,480	52,720	16,030	4,030	156,830
Percentage distribution								
1974/75	100.0	11.9	8.9	17.0	15.5	5.6	1.7	37.8
1975/76	100.0	14.1	8.1	16.6	18.2	5.4	1.5	36.0
1976/77	100.0	12.7	8.2	18.4	18.9	5.6	1.6	34.5
1977/78	100.0	12.6	8.2	16.5	24.3	5.5	1.6	31.3
1978/79	100.0	12.9	8.2	15.6	26.6	5.9	1.6	29.1
1979/80	100.0	12.6	7.9	14.8	29.2	5.4	1.4	28.6
1980/81	100.0	12.2	8.1	16.0	27.2	4.7	1.3	30.4
1981/82	100.0	12.8	8.9	17.0	22.8	4.7	1.2	32.5
1982/83	100.0	12.7	9.4	16.9	19.9	4.3	1.2	35.5
1983/84	100.0	12.3	9.4	15.5	17.9	4.6	1.2	39.0
1984/85	100.0	11.6	9.7	14.2	16.5	4.7	1.2	42.0
1985/86	100.0	9.9	10.0	13.2	15.3	4.7	1.2	45.6

¹ Details may not add to totals, which include foreign students of unknown origin.

SOURCE: Institute of International Education, *Open Doors* (annual: 1972-1986; IIE, 809 United Nations Plaza, New York, N.Y. 10017)

Science & Engineering Indicators—1987

Appendix table 2-9. Doctorates from U.S. universities: 1960-86

Year	Total	Non-S E	Total S E	Total sciences	Total engineering	Physical sciences	Mathematical sciences	Computer sciences	Life sciences	Psychology	Social sciences
1960	9,733	3,470	6,263	5,469	794	1,861	291	NA	1,660	772	885
1961	10,413	3,692	6,721	5,781	940	1,993	332	NA	1,682	820	954
1962	11,500	4,062	7,438	6,222	1,216	2,097	388	NA	1,867	856	1,014
1963	12,728	4,509	8,219	6,862	1,357	2,427	483	NA	1,976	890	1,086
1964	14,325	5,101	9,224	7,560	1,664	2,527	588	NA	2,219	1,013	1,213
1965	16,340	5,864	10,476	8,402	2,074	2,865	685	NA	2,539	954	1,359
1966	17,949	6,491	11,458	9,157	2,301	3,059	769	NA	2,711	1,139	1,479
1967	20,403	7,421	12,982	10,378	2,604	3,503	830	NA	2,966	1,295	1,784
1968	22,936	8,488	14,448	11,593	2,855	3,681	971	NA	3,511	1,464	1,966
1969	25,743	9,704	16,039	12,774	3,265	3,935	1,070	NA	3,815	1,766	2,188
1970	29,498	11,755	17,743	14,309	3,434	4,403	1,225	NA	4,165	1,890	2,626
1971	31,867	12,918	18,949	15,451	3,498	4,501	1,238	NA	4,557	2,145	3,010
1972	33,041	14,034	19,007	15,504	3,503	4,257	1,281	NA	4,454	2,279	3,233
1973	33,755	14,754	19,001	15,637	3,364	4,078	1,233	NA	4,503	2,458	3,365
1974	33,047	14,734	18,313	15,166	3,147	3,765	1,211	NA	4,304	2,598	3,288
1975	32,951	14,593	18,358	15,356	3,002	3,710	1,147	NA	4,402	2,751	3,346
1976	32,946	15,082	17,864	15,030	2,834	3,506	1,003	NA	4,361	2,883	3,277
1977	31,716	14,299	17,417	14,774	2,643	3,415	933	31	4,266	2,990	3,139
1978	30,875	13,827	17,048	14,625	2,423	3,234	838	121	4,369	3,055	3,008
1979	31,237	13,992	17,245	14,755	2,490	3,320	769	210	4,501	3,091	2,864
1980	31,017	13,818	17,199	14,720	2,479	3,149	744	218	4,715	3,098	2,796
1981	31,353	13,720	17,633	15,105	2,528	3,210	728	232	4,786	3,358	2,791
1982	31,096	13,470	17,626	14,980	2,646	3,351	720	220	4,841	3,158	2,690
1983	31,216	13,284	17,932	15,151	2,781	3,439	701	286	4,749	3,308	2,666
1984	31,277	13,208	18,069	15,156	2,913	3,459	698	295	4,869	3,223	2,609
1985	31,211	12,770	18,262	15,095	3,167	3,534	688	311	4,882	3,072	2,608
1986	31,770	12,978	18,792	15,416	3,376	3,679	730	399	4,790	3,071	2,747

Note: NA = Available

SOURCE: National Science Foundation, Division of Science Resources Studies, Science and Engineering Education Sector Studies Group, unpublished data

See figure 2-3 and table O-2 in Overview.

Science & Engineering Indicators—1987

Appendix table 2-10. Academic degrees awarded by degree level, S/E and non- S/E, and gender: 1960-86

Year	Bachelors						Masters						Doctorates					
	Number			Percent			Number			Percent			Number			Percent		
	Total	S E	Female	S E	Female		Total	S E	Female	S E	Female		Total	S E	Female	S E	Female	
1960	394,889	120,937	19,362	31	16		74,497	20,012	2,074	27	10		9,733	6,263	443	64	7	
1961	401,784	121,660	20,595	30	17		78,269	22,786	2,464	29	11		10,413	6,721	494	65	7	
1962	420,485	127,469	23,485	30	18		84,889	25,146	2,812	30	11		11,500	7,438	537	65	7	
1963	450,592	135,964	27,099	30	20		91,418	27,367	3,194	30	12		12,728	8,219	598	65	7	
1964	502,104	153,361	32,473	31	21		101,222	30,271	3,567	30	12		14,325	9,224	692	64	8	
1965	538,930	164,936	36,213	31	22		112,195	33,835	4,082	30	12		16,340	10,476	744	64	7	
1966	555,613	173,471	39,482	31	23		140,772	38,083	4,882	27	13		17,949	11,458	909	64	8	
1967	594,862	187,849	44,002	32	23		157,892	41,800	5,717	26	14		20,403	12,982	1,086	64	8	
1968	671,591	212,174	53,463	32	25		177,150	45,425	6,512	26	14		22,936	14,448	1,298	63	9	
1969	769,683	244,519	63,196	32	26		194,414	48,425	7,314	25	15		25,743	16,039	1,483	62	9	
1970	833,322	264,122	68,878	32	26		209,387	49,318	8,577	24	17		29,498	17,743	1,626	60	9	
1971	884,386	271,176	72,996	31	27		231,486	50,624	8,658	22	17		31,867	18,949	1,941	59	10	
1972	937,884	281,228	77,671	30	28		252,774	53,567	9,557	21	18		33,041	19,007	2,103	58	11	
1973	980,707	295,391	83,839	30	28		264,525	54,234	9,760	21	18		33,755	19,001	2,450	56	13	
1974	1,008,654	305,062	91,793	30	30		278,259	54,175	10,545	19	19		33,047	18,313	2,607	55	14	
1975	987,922	294,920	93,342	30	32		293,651	53,825	11,005	18	20		32,951	18,358	2,836	56	15	
1976	997,504	292,174	95,597	29	33		313,001	54,747	12,072	17	22		32,946	17,864	2,981	54	17	
1977	993,008	288,543	97,453	29	34		318,241	56,731	13,154	18	23		31,716	17,416	3,106	55	18	
1978	997,165	288,167	100,060	29	35		312,816	56,237	13,690	18	24		30,875	17,048	3,313	55	19	
1979	1,000,562	288,625	102,292	29	35		302,075	54,456	14,040	18	26		31,237	17,245	3,583	55	21	
1980	1,010,777	291,983	105,974	29	36		299,095	54,391	14,383	18	26		31,017	17,199	3,801	55	22	
1981	1,019,246	294,867	108,442	29	37		296,798	54,811	15,014	18	27		31,353	17,633	4,023	56	23	
1982	1,036,597	302,118	113,161	29	37		296,580	57,025	15,976	20	28		31,096	17,626	4,143	57	24	
1983	1,054,242	307,225	115,611	29	38		290,931	58,868	17,081	20	29		31,216	17,932	4,468	57	25	
1984	986,345	314,666	118,016	32	38		285,462	59,569	17,675	21	30		31,277	18,069	4,568	58	25	
1985	1,066,439	321,739	121,439	30	38		287,213	61,278	18,298	23	30		31,211	18,262	4,655	59	25	
1986	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA		31,770	18,792	4,906	59	26	

SOURCE: Bachelor and Master's degrees, 1960-1980: National Science Foundation, *Science and Engineering Degrees: 1950-1980* (NSF 82-307); Bachelor and Master's degrees 1980-85, and all Ph D's: National Science Foundation, Division of Science Resources Studies, Science and Engineering Education Sector Studies Group, unpublished tabulations

Science & Engineering Indicators—1987

Appendix table 2-11. Median total years from receipt of baccalaureate to earning the doctorate: 1960-84

Field of doctorate	Year of doctorate												
	1960	1962	1964	1966	1968	1970	1972	1974	1976	1978	1980	1982	1984
Total Ph.D.s	8.77	8.83	8.37	8.16	8.11	7.88	8.19	8.51	8.64	8.90	9.27	9.56	10.00
Men	8.54	8.57	8.09	7.91	7.88	7.64	8.00	8.34	8.37	8.55	8.77	8.99	9.31
Women	12.16	12.01	11.92	10.86	10.29	9.63	9.68	9.41	9.72	10.07	10.53	10.99	11.60
Physical sciences	6.49	6.51	6.18	6.04	6.02	6.11	6.53	6.78	6.74	6.98	6.85	6.89	7.20
Men	6.48	6.53	6.17	6.04	6.00	6.08	6.52	6.79	6.74	7.01	6.88	6.89	7.23
Women	7.08	6.25	6.50	6.17	6.46	6.71	6.65	6.58	6.65	6.77	6.65	6.87	7.05
Engineering	7.36	7.07	6.97	6.99	7.07	6.93	7.46	7.62	7.46	7.50	7.63	7.97	7.99
Men	7.36	7.05	6.97	6.98	7.07	6.92	7.46	7.63	7.46	7.50	7.65	8.00	8.02
Women	12.00	10.00	7.50	7.83	6.50	8.00	7.50	7.00	7.57	7.40	6.58	7.62	7.37
Life sciences	7.96	7.82	7.40	7.34	7.13	6.63	6.99	7.20	7.28	7.32	7.37	7.61	8.10
Men	7.89	7.73	7.30	7.32	7.15	6.61	6.97	7.22	7.27	7.21	7.26	7.50	8.04
Women	8.91	8.90	8.48	7.50	7.02	6.77	7.10	7.12	7.34	7.83	7.76	7.94	8.51
Social sciences	8.75	9.02	8.18	7.64	7.70	7.31	7.47	7.72	7.75	8.13	8.59	9.15	9.68
Men	8.62	8.86	8.00	7.45	7.58	7.22	7.35	7.72	7.69	8.05	8.45	8.97	9.56
Women	9.81	10.44	9.70	9.27	8.34	7.85	8.03	7.73	7.94	8.31	8.87	9.54	9.92
Humanities	10.05	10.32	9.91	9.83	9.47	9.07	8.99	9.30	9.70	10.18	10.61	11.16	11.48
Men	9.92	10.06	9.71	9.55	9.26	8.88	8.86	9.21	9.58	9.95	10.29	10.79	11.18
Women	11.67	12.14	11.19	11.08	10.45	9.73	9.44	9.52	9.95	10.53	11.21	11.70	11.94
Education	12.89	12.76	13.50	14.25	13.94	12.68	12.53	12.38	12.65	12.71	13.15	13.60	14.63
Men	12.21	12.31	13.00	13.90	13.33	12.28	12.14	12.14	12.52	12.39	12.87	13.16	14.19
Women	26.61	23.00	28.29	23.75	23.50	14.94	14.45	13.35	13.00	13.31	13.53	14.16	15.09
Professional fields	11.80	10.84	10.95	10.77	10.92	10.15	9.72	9.79	10.31	10.73	11.05	11.58	12.23
Men	10.63	10.18	10.47	10.05	10.55	9.79	9.27	9.63	10.07	10.45	10.93	11.59	11.78
Women	47.51	20.37	15.50	28.42	19.99	21.63	17.21	12.31	11.27	11.85	11.74	11.56	13.29

SOURCE: National Research Council, *Doctorate Recipients from U.S. Universities*, various issues

Science & Engineering Indicators—1987

Appendix table 2-12. Enrollment and source of support of full-time S/E graduate students in doctorate-granting institutions: 1980-86

Field and support	1980	1981	1982	1983	1984	1985	1986	Average annual percent change	
								1985-86	1980-86
								Percent	
Total science and engineering	230,535	234,194	236,939	243,540	246,718	251,147	259,980	3.5	2.0
Federal	52,939	50,897	47,206	47,415	47,687	48,964	51,367	4.9	0.5
Institutional support	86,715	90,261	93,244	96,108	100,001	102,325	107,479	5.0	3.6
Other outside support	21,066	22,382	23,630	24,430	24,535	26,427	26,718	1.1	4.0
Self support	69,815	70,654	72,859	75,587	74,495	73,431	74,416	1.3	1.1
Total sciences	188,596	189,377	188,252	190,024	191,961	195,207	200,055	2.5	1.0
Federal	41,832	39,974	36,201	35,499	36,179	37,771	39,002	3.3	1.2
Institutional support	74,081	76,161	78,075	79,869	82,774	84,049	87,502	4.1	2.8
Other outside support	14,914	15,500	15,993	16,463	15,991	16,911	16,519	2.3	1.7
Self support	57,769	57,742	57,983	58,193	57,017	56,476	57,032	1.0	0.2
Physical sciences	22,254	22,600	23,330	24,492	25,149	25,967	27,074	4.3	3.3
Federal	7,655	7,899	7,644	8,050	8,551	8,723	9,434	8.2	3.5
Institutional support	11,928	11,924	12,581	13,160	13,283	13,565	14,018	3.3	2.7
Other outside support	1,307	1,416	1,740	1,688	1,791	2,046	1,907	6.8	6.5
Self support	1,364	1,361	1,365	1,594	1,524	1,633	1,715	5.0	3.9
Environmental sciences	10,265	10,491	10,873	11,466	11,283	10,918	10,909	0.1	1.0
Federal	3,369	2,965	2,808	2,845	2,822	2,939	3,015	2.6	1.8
Institutional support	3,648	3,916	4,097	4,075	4,179	3,983	4,166	4.6	2.2
Other outside support	1,042	1,129	1,199	1,259	1,224	1,385	1,227	11.4	2.8
Self support	2,206	2,481	2,769	3,287	3,058	2,611	2,501	4.2	2.1
Mathematical sciences	9,368	9,680	10,174	10,312	10,613	11,168	11,767	5.4	3.9
Federal	842	782	802	747	755	930	992	6.7	2.8
Institutional support	6,340	6,457	6,827	7,119	7,389	7,766	8,182	5.4	4.3
Other outside support	519	526	536	507	626	543	587	8.1	2.1
Self support	1,667	1,915	2,009	1,939	1,843	1,929	2,006	4.0	3.1
Computer sciences	5,900	6,465	7,908	9,267	10,108	12,433	13,504	8.6	14.8
Federal	879	944	973	1,045	1,215	1,568	1,818	15.9	12.9
Institutional support	1,961	2,314	2,579	3,072	3,486	4,089	4,315	5.5	14.0
Other outside support	602	598	670	689	705	1,264	1,424	12.7	15.4
Self support	2,458	2,609	3,686	4,461	4,702	5,512	5,947	7.9	15.9
Agricultural sciences	9,591	9,630	9,500	9,397	9,327	8,723	8,858	1.5	1.3
Federal	1,778	1,710	1,654	1,510	1,350	1,504	1,603	6.6	1.7
Institutional support	3,359	3,448	3,444	3,576	3,821	3,369	3,517	4.4	0.8
Other outside support	2,023	2,116	2,008	2,090	1,942	1,852	1,755	5.2	2.3
Self support	2,431	2,356	2,394	2,221	2,214	1,998	1,983	0.8	3.3
Biological sciences	35,817	35,454	35,226	35,148	35,833	35,983	36,916	2.6	0.5
Federal	10,725	10,505	10,055	10,131	10,456	10,763	11,205	4.1	0.7
Institutional support	15,546	15,674	15,796	15,843	16,419	16,465	17,101	3.9	1.6
Other outside support	2,731	2,746	3,053	3,160	3,093	3,250	3,094	4.8	2.1
Self support	6,815	6,529	6,322	6,014	5,865	5,505	5,516	0.2	3.5
Health sciences	22,303	22,111	20,927	20,553	20,884	21,406	21,431	0.1	0.7
Federal	8,184	7,653	6,120	5,556	5,563	5,966	5,797	2.8	5.6
Institutional support	4,437	4,314	4,612	4,673	5,114	5,380	5,653	5.1	4.1
Other outside support	1,197	1,257	1,270	1,559	1,597	1,636	1,573	3.9	4.7
Self support	8,485	8,887	8,925	8,765	8,610	8,424	8,408	0.2	0.2
Psychology	21,580	21,544	21,103	21,309	21,578	21,524	22,007	2.2	0.3
Federal	3,189	2,895	2,283	1,980	1,942	1,958	1,893	3.3	8.3
Institutional support	7,869	8,614	8,557	8,778	9,229	9,540	9,922	4.0	3.9
Other outside support	1,438	1,505	1,377	1,316	1,325	1,326	1,327	0.1	1.3
Self support	9,084	8,530	8,886	9,235	9,082	8,700	8,865	1.9	0.4
Social sciences	51,518	51,402	49,211	43,080	47,186	47,085	47,589	1.1	1.3
Federal	5,211	4,621	3,862	3,635	3,525	3,420	3,245	5.1	7.6
Institutional support	18,993	19,500	19,582	19,573	19,854	19,892	20,628	3.7	1.4
Other outside support	4,055	4,207	4,140	4,195	3,688	3,609	3,625	0.4	1.9
Self support	23,259	23,074	21,627	20,677	20,119	20,164	20,091	0.4	2.4
Total engineering	41,939	44,817	48,687	53,516	54,757	55,940	59,925	7.1	6.1
Federal	11,107	10,923	11,005	11,916	11,508	11,193	12,365	10.5	1.8
Institutional support	12,634	14,100	15,169	16,239	17,227	18,276	19,977	9.3	7.9
Other outside support	6,152	6,882	7,637	7,967	8,544	9,516	10,199	7.2	8.8
Self support	12,046	12,912	14,876	17,394	17,478	16,955	17,384	2.5	6.3

SOURCE: National Science Foundation, *Academic Science Engineering: Graduate Enrollment and Support, Fall 1986* (forthcoming)

See figure 2-4.

Science & Engineering Indicators—1987

Appendix table 2-13. Full-time S E graduate students in doctorate-granting institutions, by field and type of major support: 1980-86

Field and type of major support	1980	1981	1982	1983	1984	1985	1986	Average annual percent change	
								1985-86	1980-86
								Percent	
Total sciences and engineering	230,535	234,194	236,939	243,540	246,718	251,147	259,980	3.5	2.0
Fellowships and traineeships	38,901	37,653	35,979	35,368	35,734	36,888	37,345	1.2	0.7
Research assistantships	50,781	51,946	51,828	54,146	56,946	60,448	65,560	8.5	4.3
Teaching assistantships	51,838	53,800	56,068	57,872	59,160	60,054	60,927	1.5	2.7
Other types of support	19,200	20,141	20,205	20,547	20,383	20,326	21,732	3.1	1.8
Self-support	69,815	70,654	72,859	75,587	74,495	73,431	74,416	1.3	1.1
Total engineering	41,939	44,817	48,687	53,516	54,757	55,940	59,925	7.1	6.1
Fellowships and traineeships	4,603	5,032	5,416	5,576	5,596	5,571	5,781	3.8	3.9
Research assistantships	13,928	14,394	14,595	15,581	16,206	17,858	20,407	14.3	6.6
Teaching assistantships	7,245	8,155	8,952	9,901	10,369	10,575	10,973	3.8	7.2
Other types of support	4,117	4,324	4,848	5,064	5,108	4,981	5,380	4.0	1.8
Self-support	12,046	12,912	14,876	17,394	17,478	16,955	17,384	2.5	6.3
Total sciences	188,596	189,377	188,252	190,024	191,961	195,207	200,055	2.5	1.0
Fellowships and traineeships	34,298	32,621	30,563	29,812	30,138	31,317	31,564	0.8	1.4
Research assistantships	36,853	37,552	37,233	38,565	40,740	42,590	45,153	6.0	3.4
Teaching assistantships	44,593	45,645	47,116	47,971	48,791	49,479	49,954	1.0	1.9
Other types of support	15,083	15,817	15,357	15,483	15,275	15,345	16,352	2.7	1.4
Self-support	57,769	57,742	57,983	58,193	57,017	56,476	57,032	1.0	0.2
Physical sciences	22,254	22,600	23,330	24,492	25,149	25,967	27,074	4.3	3.3
Fellowships and traineeships	2,183	2,237	2,285	2,288	2,413	2,301	2,376	3.3	1.4
Research assistantships	8,258	8,524	8,683	9,060	9,517	10,174	10,847	3.3	1.4
Teaching assistantships	9,894	9,976	10,361	10,898	10,979	11,148	11,329	6.6	4.6
Other types of support	555	502	636	652	716	711	807	6.9	5.5
Self-support	1,364	1,361	1,365	1,594	1,524	1,633	1,715	5.0	3.9
Environmental sciences	10,265	10,491	10,873	11,466	11,283	10,918	10,909	0.1	1.0
Fellowships and traineeships	1,107	1,095	1,140	1,147	1,117	1,139	989	13.2	1.9
Research assistantships	3,664	3,402	3,265	3,481	3,506	3,676	3,789	3.1	0.6
Teaching assistantships	2,563	2,541	2,737	2,752	2,743	2,541	2,554	0.5	0.1
Other types of support	725	972	962	799	859	951	1,076	6.4	5.8
Self-support	2,206	2,481	2,769	3,287	3,058	2,611	2,501	4.2	2.1
Mathematical sciences	9,368	9,680	10,174	10,312	10,613	11,168	11,767	5.4	3.9
Fellowships and traineeships	891	799	788	800	901	992	1,007	1.5	2.1
Research assistantships	773	732	822	775	846	969	1,017	4.4	4.6
Teaching assistantships	5,373	5,536	5,817	6,140	6,325	6,553	6,897	5.2	4.2
Other types of support	664	698	738	658	698	725	840	7.6	3.4
Self-support	1,667	1,915	2,009	1,939	1,843	1,929	2,006	4.0	3.1
Computer sciences	5,900	6,465	7,908	9,267	10,108	12,433	13,504	8.6	14.8
Fellowships and traineeships	367	473	463	524	612	807	893	10.7	16.0
Research assistantships	1,023	1,068	1,151	1,367	1,582	2,020	2,284	13.1	14.3
Teaching assistantships	1,409	1,742	1,955	2,311	2,646	3,089	3,109	0.6	14.1
Other types of support	643	573	653	604	566	1,005	1,271	11.9	10.2
Self-support	2,458	2,609	3,686	4,461	4,702	5,512	5,947	7.9	15.9
Agricultural sciences	9,591	9,630	9,500	9,397	9,327	8,723	8,858	1.5	1.3
Fellowships and traineeships	772	793	779	759	666	657	649	1.2	2.9
Research assistantships	4,484	4,647	4,558	4,509	4,612	4,308	4,612	7.1	0.5
Teaching assistantships	888	805	883	879	837	824	752	8.7	2.7
Other types of support	1,016	1,029	886	1,029	998	936	862	8.0	2.4
Self-support	2,431	2,356	2,394	2,221	2,214	1,998	1,983	0.8	3.3
Biological sciences	35,817	35,454	35,226	35,148	35,833	35,983	36,916	2.6	0.5
Fellowships and traineeships	8,160	7,967	7,845	7,928	8,122	8,343	8,606	3.2	0.9
Research assistantships	9,545	9,801	9,774	9,986	10,820	11,189	12,059	7.8	4.0
Teaching assistantships	9,120	9,037	9,155	8,956	8,914	8,936	8,609	3.7	1.0
Other types of support	2,177	2,120	2,130	2,264	2,112	2,010	2,126	2.7	0.3
Self-support	6,815	6,529	6,322	6,014	5,865	5,505	5,516	0.2	3.5
Health sciences	22,303	22,111	20,927	20,553	20,884	21,406	21,431	0.1	0.7
Fellowships and traineeships	8,034	7,691	6,704	6,033	6,034	6,505	6,318	2.9	3.9
Research assistantships	1,448	1,477	1,493	1,567	1,797	2,160	2,320	7.4	8.2
Teaching assistantships	1,960	1,949	2,071	2,077	2,210	2,188	2,288	4.6	2.6
Other types of support	2,376	2,107	1,734	2,111	2,233	2,129	2,097	4.4	1.8
Self-support	8,485	8,887	8,925	8,765	8,610	8,424	8,408	0.2	0.2
Psychology	21,580	21,544	21,103	21,309	21,578	21,524	22,007	2.2	0.3
Fellowships and traineeships	3,447	3,167	2,915	2,546	2,635	2,769	2,588	6.5	4.7
Research assistantships	2,342	2,664	2,510	2,657	2,762	2,867	2,889	0.8	3.6
Teaching assistantships	4,424	4,604	4,550	4,640	4,669	4,817	4,974	3.3	2.0
Other types of support	2,283	2,579	2,242	2,231	2,430	2,371	2,691	6.6	2.3
Self-support	9,084	8,530	8,886	9,235	9,082	8,700	8,865	1.9	0.4
Social sciences	51,518	51,402	49,211	48,080	47,186	47,085	47,589	1.1	1.3
Fellowships and traineeships	9,337	8,399	7,644	7,787	7,638	7,804	8,138	4.3	2.3
Research assistantships	5,316	5,237	4,977	5,164	5,298	5,227	5,341	2.2	0.1
Teaching assistantships	8,962	9,455	9,587	9,318	9,468	9,383	9,442	0.6	0.9
Other types of support	4,644	5,237	5,376	5,134	4,663	4,507	4,577	0.3	0.2
Self-support	23,259	23,074	21,627	20,677	20,119	20,164	20,091	0.4	2.4

SOURCE: National Science Foundation. *Academic Science Engineering Graduate Enrollment and Support, Fall 1986* (forthcoming).

Science & Engineering Indicators—1987

Appendix table 2-14. Baccalaureate sources of 1984 S/E doctorate recipients, by institutional type

Field	Total	Total Classified	Research institutions	Other doctorate- granting institutions	Comprehensive institutions	Liberal arts colleges	Specialized institutions
Percent of classified institutions							
Physical sciences	3,212	3,212	31.3	27.1	25.1	14.2	2.3
Physics and astronomy	767	767	42.8	25.9	18.8	9.4	3.1
Chemistry	1,373	1,373	21.8	28.0	31.8	16.9	1.4
Earth, atmospheric and marine sciences.	486	486	34.8	27.4	19.8	14.8	3.3
Mathematics and computer sciences	586	586	35.5	26.3	22.0	13.8	2.4
Life sciences	4,670	4,661	34.3	31.0	21.4	11.8	1.5
Biological sciences	3,353	3,349	34.7	29.5	22.0	12.9	0.9
Health sciences	588	587	27.4	31.0	24.2	12.3	5.1
Agricultural sciences	729	725	38.2	37.9	16.3	6.2	1.4
Social sciences	4,866	4,860	28.2	29.8	26.2	15.2	0.7
Psychology	2,919	2,916	26.2	29.5	27.8	15.8	0.7
Economics	472	471	33.3	33.8	19.3	13.2	0.4
Anthropology and sociology	714	712	30.5	28.5	24.6	16.2	0.3
Political sciences	396.0	396.0	30.3	29.0	26.3	12.1	2.3
Engineering	1,394	1,394	47.7	31.0	12.3	3.9	5.0

SOURCE: National Research Council, *Doctorate Recipients from U.S. Universities, Summary Report 1984*, p. 13

See figure 2-5.

Science & Engineering Indicators—1987

Appendix table 2-15. Baccalaureate origins of Ph.D.'s for selected categories of undergraduate institutions: pre-1963, 1963-72, 1973-82

Baccalaureate school ¹	Engineering			Physical sciences ²			Environmental sciences ³			Biological sciences			Social sciences			Non S/E fields		
	Pre-1963	1963-72	1973-82	Pre-1963	1963-72	1973-82	Pre-1963	1963-72	1973-82	Pre-1963	1963-72	1973-82	Pre-1963	1963-72	1973-82	Pre-1963	1963-72	1973-82
Percent																		
Schools granting doctorates 1981/1982:																		
Schools granting > 40 S/E																		
Ph.D's (171) ¹	68.4	60.0	44.3	56.9	49.3	43.4	63.1	57.2	53.0	59.8	47.2	48.4	22.3	49.6	47.6	47.3	42.0	39.2
Schools granting 40 or fewer S/E																		
Ph.D's (143)	1.9	5.8	5.0	5.5	6.8	6.8	3.8	4.7	5.9	5.7	6.3	6.6	5.1	5.7	6.8	7.2	8.7	9.1
Nondoctoral schools 1981/1982:																		
Schools granting up to Master's (1,096)	7.5	8.3	7.6	27.7	26.8	25.0	16.6	19.8	22.1	19.8	24.6	25.0	26.7	30.7	30.8	35.7	38.3	38.7
Schools granting Bachelor's (329)	0.3	0.4	0.7	1.5	1.2	1.5	0.4	0.6	0.9	1.0	1.2	1.5	1.1	0.9	1.6	2.0	1.8	2.4
Foreign schools (NA)	18.9	24.8	39.3	7.7	14.7	21.3	15.4	16.8	16.4	12.2	18.3	15.7	8.4	12.0	10.7	5.7	7.4	8.2

¹Number of institutions in each category in parentheses.

²Includes physics, mathematics, and chemistry.

³Includes astronomy, atmospheric, earth and ocean sciences.

Note: Data may not add to 100% because defunct and unknown institutions are omitted.

SOURCE: National Research Council and Lois Peters, unpublished tabulations.

Science & Engineering Indicators—1987

Appendix table 2-16. Type of baccalaureate institution of 1983-85 S/E doctorate recipients, by gender and race of recipients

	All institutions	Type of baccalaureate institution ¹						Non-U.S. institutions
		I	II	III	IV	V	Unclassified & unknown	
All doctorates:								
Number	41,249	12,651	11,287	8,898	4,857	690	448	2,418
Percent	100	31	27	22	12	2	1	6
Men:								
Number	29,267	9,153	8,160	6,270	2,875	610	323	1,875
Percent	100	31	28	21	10	2	1	6
Women:								
Number	11,982	3,498	3,127	2,627	1,982	80	125	543
Percent	100	29	26	22	17	1	1	5
Native American:								
Number	99	20	39	24	8	5	2	1
Percent	100	20	39	24	8	5	2	1
Asian:								
Number	2,331	525	205	130	99	13	29	1,330
Percent	100	23	9	6	4	1	1	57
Black:								
Number	972	196	190	358	162	10	8	48
Percent	100	20	20	37	17	1	1	5
Hispanic:								
Number	831	182	158	309	59	11	25	87
Percent	100	22	19	37	7	1	3	10
White:								
Number	35,885	11,352	10,429	7,872	4,397	628	319	888
Percent	100	32	29	22	12	2	1	2
Other & unknown								
Number	1,131	376	266	205	132	23	65	64
Percent	100	33	24	18	12	2	6	6

¹Modified Carnegie Commission classification. See notes on appendix table 2-17.

SOURCE: National Science Foundation, Division of Science Resources Studies, *Baccalaureate Origins of Science and Engineering Doctorate Recipients*, (forthcoming)

Science & Engineering Indicators—1987

Appendix table 2-17. Baccalaureate origins: producers of baccalaureates receiving 1984 doctorates

Top 30 producers in absolute numbers			Top 30 producers relative to total class of 1974 baccalaureates		
Institution ¹	Number of baccalaureates	Institutional type ²	Institution ¹	Number of baccalaureates	Institutional type ²
University of California-Berkeley	364	I, Public	California Institute of Technology	71 195	I, Private
University of Michigan	307	I, Public	Harvey Mudd College CA	24 71	IV, Private
University of Illinois	267	I, Public	Reed College OR	43 205	IV, Private
University of California-Los Angeles	253	I, Public	University of Chicago IL	87 446	I, Private
University of Wisconsin	242	I, Public	Swarthmore College PA	53 280	IV, Private
Pennsylvania State University	224	I, Public	Massachusetts Institute of Technology	200 1065	I, Private
Cornell University	217	I, Private	Haverford College PA	27 162	IV, Private
Ohio State University	207	I, Public	Oberlin College OH	95 623	IV, Private
Michigan State University	202	I, Public	Kalamazoo College MI	32 218	IV, Private
Massachusetts Institute of Technology	200	I, Private	Harvard University MA	157 1122	I, Private
University of Texas-Austin	197	I, Public	Carleton College MN	46 333	IV, Private
University of Maryland	192	I, Public	Brandeis University MA	73 531	II, Private
University of Minnesota	189	I, Public	Princeton University NJ	127 936	I, Private
University of Washington	168	I, Public	Cornell University NY	217 1616	I, Private
Rutgers, The State University	166	II, Public	Pomona College CA	44 331	IV, Private
Harvard University	157	I, Private	Barnard College NY	66 497	IV, Private
Stanford University	156	I, Private	Bryn Mawr College PA	28 211	IV, Private
Indiana University	149	II, Public	Wellesley College MA	60 467	IV, Private
SUNY-Buffalo	145	II, Public	St. Mary's Seminary & University MD	6 51	IV, Private
University of Pennsylvania	144	I, Private	Wesleyan University CT	46 392	IV, Private
CUNY-Brooklyn	140	III, Public	New College FL	17 147	IV, Private
Purdue University	138	I, Public	Amherst College MA	35 309	IV, Private
University of Massachusetts	135	II, Public	Brown University RI	111 1012	II, Private
Brigham Young University	132	II, Private	Rice University TX	68 650	II, Private
University of Missouri	132	I, Public	Point Loma College CA	13 126	III, Private
University of California-Santa Barbara	130	II, Public	Yale University CT	124 1237	I, Private
Princeton University	127	I, Private	Williams College MA	37 372	IV, Private
University of Colorado	125	I, Public	University of Rochester NY	116 1171	I, Private
University of Florida	125	I, Public	Grinnell College IA	30 303	IV, Private
Yale University	124	I, Private	New England Conserv Music MA	5 52	V, Private

¹ Population limited to institutions granting 50 or more baccalaureate degrees in 1974.

² Carnegie classification: I = Research Institutions, II = Other Doctorate Institutions; III = Comprehensive Institutions, IV = Liberal Arts Colleges, V = Other Specialized Institutions

SOURCE: National Research Council, *Doctorate Recipients from U.S. Universities, Summary Report 1984*, p 18

Science & Engineering Indicators—1987

Appendix table 2-18. Leading baccalaureate sources of 1984 S/E Ph.D.'s, by productivity and by institutional type

Institution ¹	Ratio of 1984 Ph.D.'s to 1974 ² baccalaureates	Type ³
Physical sciences:		
Harvey Mudd College/CA	20/71	IV, Private
California Institute of Technology	41/195	I, Private
Massachusetts Institute of Technology	76/1065	I, Private
Swarthmore College/PA	16/280	IV, Private
Reed College/OR	10/205	IV, Private
Carleton College/MN	13/333	IV, Private
University of Chicago/IL	15/446	I, Private
Washington College/MD	5/149	IV, Private
University of California-San Diego	32/991	I, Private
Colorado School of Mines	8/255	V, Public
Engineering:		
California Institute of Technology	23/195	I, Private
Massachusetts Institute of Technology	63/1065	I, Private
Stevens Institute/NJ	8/256	V, Private
Harvey Mudd College/CA	2/71	IV, Private
Rensselaer Polytechnic Institute/NY	21/805	II, Private
Cornell University/NY	31/1616	I, Private
Carnegie-Mellon University/PA	12/648	II, Private
Worcester Polytechnic Institute/MA	7/392	V, Private
Clarkson College of Technology/NY	10/572	V, Private
Rice University/TX	11/650	II, Private
Life sciences:		
Reed College/OR	12/205	IV, Private
University of Chicago/IL	22/446	I, Private
Cornell University/NY	73/1616	I, Private
Kalamazoo College/MI	8/218	IV, Private
California Institute of Technology	7/195	I, Private
Thomas Jefferson University/PA	2/58	V, Private
Brandeis University/MA	18/531	II, Private
Harvard University/MA	37/1122	I, Private
Massachusetts Institute of Technology	34/1065	I, Private
St. Johns College/MD	2/63	IV, Private
Social sciences:		
St. Mary's Seminary and University/MD	4/51	IV, Private
University of Chicago/IL	29/446	I, Private
Swarthmore College/PA	16/280	IV, Private
Brandeis University/MA	27/531	II, Private
Barnard College-Columbia Univ/NY	25/497	IV, Private
Reed College/OR	10/205	IV, Private
New College/FL	7/147	IV, Private
Sarah Lawrence College/NY	10/219	IV, Private
Oberlin College/OH	28/623	IV, Private
Bryn Mawr College/PA	9/211	IV, Private

¹ Named institutions refer to main campuses, unless otherwise noted. Some institution names have changed since 1974: Clarkson College of Technology is Clarkson University; New College has affiliated with the University of South Florida and is a public Other Doctorate-Granting Institution.

² "Productivity" of 1984 Ph.D.'s in each field from schools that graduated 50 or more students in any category in 1974

³ See appendix table 2-17 for type classification.

SOURCE: National Research Council, *Doctorate Recipients from U.S. Universities, Summary Report 1984*, p. 45

Science & Engineering Indicators—1987

Appendix table 2-19. Academic¹ doctoral scientists and engineers, by age and field: 1977, 1981, 1983, and 1985

Fields	Years	Number	Age (years)				
			Under 30	30-39	40-49	50-59	60 +
			Percent				
Total scientists and engineers	1977	157,088	3.4	41.1	29.6	19.0	6.9
	1981	179,224	2.5	35.5	32.2	20.7	9.1
	1983	187,554	1.8	31.4	34.8	21.6	10.3
	1985	202,019	1.6	30.3	35.7	21.0	11.3
Total scientists	1977	141,373	3.5	41.6	28.9	18.8	7.1
	1981	161,247	2.6	36.4	31.6	20.1	9.3
	1983	167,305	1.8	32.0	34.4	21.3	10.4
	1985	180,505	1.5	30.7	36.0	20.4	11.3
Physical scientists	1977	25,556	4.2	41.4	30.7	16.8	6.9
	1981	26,786	3.4	30.5	34.5	20.6	11.0
	1983	26,453	2.5	24.4	38.8	22.6	11.8
	1985	28,206	2.2	25.3	37.2	22.7	12.6
Mathematical scientists	1977	11,781	4.5	48.6	27.9	13.2	5.7
	1981	12,274	3.1	35.0	38.3	16.6	7.0
	1983	12,770	2.2	28.2	42.3	19.1	8.2
	1985	13,027	2.8	25.4	40.1	22.2	9.5
Computer specialists	1977	2,118	4.6	52.2	27.9	13.4	1.9
	1981	2,954	3.0	45.4	31.6	15.5	4.5
	1983	3,905	2.1	45.8	32.0	13.1	6.9
	1985	5,124	1.9	38.8	40.3	12.9	6.0
Environmental scientists	1977	6,120	1.5	43.1	31.4	18.3	5.6
	1981	6,613	3.1	33.3	37.7	17.8	8.1
	1983	6,519	1.8	35.3	31.6	21.2	10.1
	1985	7,097	1.3	30.6	34.6	23.1	10.2
Life scientists	1977	45,643	3.5	41.7	27.8	19.6	7.3
	1981	54,437	2.9	39.5	29.5	19.7	8.4
	1983	57,315	1.9	34.9	32.8	20.7	9.6
	1985	61,788	1.4	34.0	34.5	19.9	10.2
Psychologists	1977	16,572	5.1	41.9	28.0	19.3	5.7
	1981	19,034	2.9	41.6	27.9	20.1	7.4
	1983	19,377	1.5	37.8	30.5	21.6	8.4
	1985	21,493	1.5	36.6	31.6	19.7	10.5
Social scientists	1977	33,583	2.2	38.1	29.5	21.2	8.9
	1981	39,149	1.3	33.8	31.2	22.2	11.5
	1983	40,966	1.1	29.5	34.1	22.5	12.7
	1985	43,770	0.9	27.2	38.1	20.1	13.7
Total engineers	1977	15,715	1.8	36.2	36.0	21.1	4.9
	1981	17,977	1.2	27.4	37.8	25.9	7.8
	1983	20,249	2.1	26.1	38.2	24.0	9.7
	1985	21,514	2.2	27.6	33.1	25.2	11.9

¹ Includes individuals employed in four-year colleges and universities only.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, Detailed Statistical Tables* (biennial series)

See figure 2-6.

Science & Engineering Indicators—1987

Appendix table 2-20. Academic doctoral scientists and engineers, by primary work activity and field: 1981, 1983, and 1985

Fields	Research and development								
	Total	Total	Basic	Applied	Development	Management	Teaching	Consulting	Other
			Research	Research		of R&D			
1981									
Total scientists and engineers	179,224	56,813	37,746	13,689	1,015	4,363	99,247	772	22,392
Total scientists	161,247	51,774	36,167	11,344	823	3,440	88,787	562	20,124
Physical scientists	26,786	10,532	7,795	1,650	259	828	14,118	53	2,083
Mathematical scientists	12,274	2,015	1,631	319	21	44	9,152	3	1,077
Computer specialists	2,954	901	389	181	253	78	1,469	63	521
Environmental scientists	6,613	2,754	1,660	642	76	376	3,436	0	423
Life scientists	54,437	27,002	20,156	5,509	123	1,214	20,400	151	6,884
Psychologists	19,034	3,519	2,095	1,116	26	282	11,620	119	3,776
Social scientists	39,149	5,051	2,441	1,927	65	618	28,592	146	5,360
Total engineers	17,977	5,039	1,579	2,345	192	923	10,460	210	2,268
1983									
Total scientists and engineers	187,554	57,557	39,443	13,584	1,509	3,021	100,452	684	28,861
Total scientists	167,305	51,667	37,210	11,138	970	2,349	89,233	618	25,787
Physical scientists	26,453	10,224	7,510	1,551	273	890	13,044	30	3,182
Mathematical scientists	12,770	2,108	1,659	348	44	57	9,214	79	1,369
Computer specialists	3,905	1,071	488	211	311	61	2,117	33	684
Environmental scientists	6,519	2,572	1,755	564	0	253	3,250	13	684
Life scientists	57,315	27,282	21,078	5,223	225	756	20,805	311	8,917
Psychologists	19,377	3,217	2,040	1,040	24	113	11,478	121	4,561
Social scientists	40,966	5,193	2,680	2,201	93	219	29,325	58	6,390
Total engineers	20,249	5,890	2,233	2,446	539	672	11,219	66	3,074
1985									
Total scientists and engineers	202,019	64,487	43,579	15,653	1,318	3,937	103,652	1,204	32,676
Total scientists	180,505	58,246	41,194	13,269	914	2,869	91,761	1,064	29,434
Physical scientists	28,206	11,570	8,703	1,745	247	875	13,545	14	3,077
Mathematical scientists	13,027	2,469	2,089	304	3	73	8,904	119	1,535
Computer specialists	5,124	1,481	744	337	311	89	2,629	68	946
Environmental scientists	7,097	3,051	1,940	721	40	350	3,231	23	792
Life scientists	61,788	30,113	22,749	6,104	252	1,008	20,676	342	10,657
Psychologists	21,493	3,681	2,074	1,447	35	125	11,953	325	5,534
Social scientists	43,770	5,881	2,895	2,611	26	349	30,823	173	6,893
Total engineers	21,514	6,241	2,385	2,384	404	1,068	11,891	140	3,242

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, Detailed Statistical Tables* (biennial series)
Science & Engineering Indicators—1987

Appendix table 2-21. Academic doctoral scientists and engineers who teach, by field and rank: 1981, 1983, and 1985

Field	Total	Professor	Associate Professor	Assistant Professor	Instructor	Other	No report
1981							
Total scientists and engineers	130,597	57,295	38,257	28,714	1,237	4,133	326
Total scientists	117,417	50,089	34,577	26,774	1,237	3,831	326
Physical scientists	18,423	9,938	4,745	2,701	134	686	61
Mathematical scientists	10,804	4,924	3,377	2,125	160	177	25
Computer specialists	1,950	579	717	549	30	54	0
Environmental scientists	4,416	1,972	1,319	1,034	6	79	0
Life scientists	33,893	13,278	10,248	8,140	535	1,528	89
Psychologists	14,902	5,779	4,346	3,876	101	584	100
Social scientists	33,029	13,619	9,825	8,349	271	723	51
Total engineers	13,180	7,206	3,680	1,940	0	302	0
1983							
Total scientists and engineers	135,990	62,358	40,789	26,529	745	4,171	1,398
Total scientists	121,088	54,311	36,557	24,267	743	3,918	1,292
Physical scientists	17,656	10,546	4,074	2,281	102	521	132
Mathematical scientists	11,289	5,295	3,523	2,148	115	132	76
Computer specialists	2,559	842	898	688	5	117	9
Environmental scientists	4,505	2,073	1,291	957	4	129	51
Life scientists	35,415	14,911	10,693	7,497	258	1,669	387
Psychologists	14,956	6,157	4,822	3,195	110	429	243
Social scientists	34,708	14,487	11,256	7,501	149	921	394
Total engineers	14,902	8,047	4,232	2,262	2	253	106
1985							
Total scientists and engineers	143,360	64,103	41,265	29,110	1,453	6,550	879
Total scientists	127,583	56,228	37,181	25,965	1,451	6,005	753
Physical scientists	18,749	10,677	4,100	2,669	229	947	127
Mathematical scientists	11,567	5,702	3,136	2,292	142	230	65
Computer specialists	3,619	1,009	1,276	1,039	46	247	2
Environmental scientists	4,550	2,251	1,227	915	26	117	14
Life scientists	35,956	14,683	11,038	7,437	423	2,197	178
Psychologists	16,029	6,649	4,826	3,328	252	822	152
Social scientists	37,113	15,257	11,578	8,285	333	1,445	215
Total engineers	15,777	7,875	4,084	3,145	2	545	126

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, Detailed Statistical Tables* (biennial series)

Science & Engineering Indicators—1987

Appendix table 2-22. Full-time S/E graduate students in doctorate-granting institutions, by gender, support, and field: 1986

	Engineering		Physical sciences		Environmental sciences		Mathematical sciences		Computer sciences		Life sciences		Psychology		Social sciences	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Enrollment	52,760	7,165	21,539	5,535	8,091	2,818	8,599	3,168	10,610	2,894	34,680	32,525	8,890	13,117	26,627	20,962
Support:																
Federal	11,043	1,322	7,714	1,720	2,277	738	808	184	1,588	230	9,187	9,418	792	1,101	1,769	1,476
DOD	3,783	310	966	176	383	70	363	66	898	116	264	167	73	59	124	26
HHS	448	142	1,442	550	18	20	13	11	40	5	5,669	6,774	376	568	153	390
NIH	366	118	1,310	517	13	11	11	8	39	4	5,115	3,746	237	348	86	191
Other HHS	82	24	132	33	5	9	2	3	1	1	554	3,028	139	220	67	199
NSF	2,744	367	3,063	598	1,010	340	289	68	452	75	716	483	96	135	228	140
Other federal	4,068	503	2,243	396	866	308	143	39	198	34	2,538	1,994	247	339	1,264	920
Institutional support ...	17,440	2,537	10,917	3,101	2,972	1,194	5,911	2,271	3,368	947	14,575	11,696	3,944	5,978	11,950	8,678
Other outside support .	9,131	1,068	1,518	389	995	232	484	103	1,160	264	4,195	2,227	573	754	2,482	1,143
Other U.S.	7,127	957	1,234	332	716	197	197	48	926	225	2,389	1,716	539	727	1,113	790
Foreign	2,004	111	284	57	279	35	287	55	234	39	1,806	511	34	27	1,369	353
Self-support	15,146	2,238	1,390	325	1,847	654	1,396	610	4,494	1,453	6,723	9,184	3,581	5,284	10,426	9,665
Percent																
Enrollment	88.0	12.0	79.6	20.4	74.2	25.8	73.1	26.9	78.6	21.4	51.6	48.4	40.4	59.6	56.0	44.0
Support:																
Federal	89.3	10.7	81.8	18.2	75.5	24.5	81.5	18.5	87.3	12.7	49.4	50.6	41.8	58.2	54.5	45.5
DOD	92.4	7.6	84.6	15.4	84.5	15.5	84.6	15.4	88.6	11.4	61.3	38.7	55.3	44.7	82.7	17.3
HHS	75.9	24.1	72.4	27.6	47.4	52.6	54.2	45.8	88.9	11.1	45.6	54.4	39.8	60.2	28.2	71.8
NIH	75.6	24.4	71.7	28.3	54.2	45.8	57.9	42.1	90.7	9.3	57.7	42.3	40.5	59.5	31.0	69.0
Other HHS	77.4	22.6	80.0	20.0	35.7	64.3	40.0	60.0	50.0	50.0	15.5	84.5	38.7	61.3	25.2	74.8
NSF	88.2	11.8	83.7	16.3	74.8	25.2	81.0	19.0	85.8	14.2	59.7	40.3	41.6	58.4	62.0	38.0
Other federal	89.0	11.0	85.0	15.0	73.8	26.2	78.6	21.4	85.3	14.7	56.0	44.0	42.2	57.8	57.9	42.1
Institutional support ...	87.3	12.7	77.9	22.1	71.3	28.7	72.2	27.8	78.1	21.9	55.5	44.5	39.8	60.2	57.9	42.1
Other outside support .	89.5	10.5	79.6	20.4	81.1	18.9	82.5	17.5	81.5	18.5	65.3	34.7	43.2	56.8	68.5	31.5
Other U.S.	88.2	11.8	78.8	21.2	78.4	21.6	80.4	19.6	80.5	19.5	58.2	41.8	42.6	57.4	58.5	41.5
Foreign	94.8	5.2	83.3	16.7	88.9	11.1	83.9	16.1	85.7	14.3	77.9	22.1	55.7	44.3	79.5	20.5
Self-support	87.1	12.9	81.0	19.0	73.9	26.1	69.6	30.4	75.6	24.4	42.3	57.7	40.4	59.6	51.9	48.1

SOURCE: National Science Foundation, *Academic Science Engineering: Graduate Enrollment and Support, Fall 1986* (forthcoming)

Science & Engineering Indicators—1987

**Appendix table 3-1. Employment status of scientists and engineers,
by field and gender: 1976, 1980, 1986**

Field and gender	Total Employed			Employed in S E		
	1976	1980	1986	1976	1980	1986
Total, all S/E fields	2,331,200	2,860,400	4,626,500	2,122,100	2,542,700	3,919,900
Men	2,131,600	2,544,800	3,927,800	1,947,200	2,269,900	3,393,700
Women	199,700	315,600	698,600	174,900	272,800	526,700
Total scientists	959,500	1,184,500	2,186,300	843,800	1,032,800	1,676,400
Men	781,300	918,000	1,586,700	689,100	806,200	1,242,800
Women	178,200	266,500	599,600	154,700	226,600	433,600
Physical scientists	188,900	215,200	288,400	154,900	166,300	264,900
Men	172,700	194,500	250,100	143,600	151,700	229,500
Women	16,200	20,800	38,300	11,300	14,500	35,400
Mathematical scientists	48,600	64,300	131,000	43,800	57,300	103,900
Men	37,100	46,400	97,100	33,700	42,100	78,900
Women	11,500	13,000	33,900	10,000	15,200	25,000
Computer specialists	119,000	207,800	562,600	116,000	196,700	437,200
Men	98,400	149,900	400,000	95,100	147,600	308,700
Women	20,600	57,900	162,500	20,900	49,100	128,400
Environmental scientists	54,800	77,600	111,300	46,600	63,100	97,300
Men	50,900	66,800	98,400	44,000	54,700	87,200
Women	3,900	10,700	12,900	2,600	8,400	10,100
Life scientists	213,500	287,500	411,800	198,200	267,300	340,500
Men	179,600	234,400	309,000	167,700	218,400	257,100
Women	33,900	53,100	102,800	30,500	48,900	83,300
Psychologists	112,500	128,100	253,500	103,700	112,500	172,800
Men	76,900	79,400	138,400	71,600	70,400	99,500
Women	35,600	48,700	115,200	32,000	42,100	73,300
Social scientists	222,300	204,000	427,800	180,500	169,700	259,800
Men	165,700	146,700	293,800	133,200	121,300	181,800
Women	56,600	57,200	134,000	47,300	48,300	78,000
Total engineers	1,371,700	1,675,900	2,440,100	1,278,300	1,509,900	2,243,500
Men	1,350,300	1,626,700	2,341,100	1,258,100	1,463,600	2,150,900
Women	21,400	49,200	99,000	20,200	46,200	92,600
Aeronautical/astronautical	56,800	69,500	110,500	55,700	65,000	104,200
Men	56,400	68,300	106,200	55,100	63,700	100,300
Women	400	1,200	4,300	600	1,300	3,900
Chemical	77,500	94,500	149,000	76,400	89,000	131,500
Men	75,000	90,000	137,800	73,700	84,500	121,200
Women	2,500	4,500	11,200	2,800	4,500	10,300
Civil	188,200	232,100	346,300	182,800	217,000	319,100
Men	182,800	226,300	333,400	178,100	211,500	307,200
Women	5,400	5,800	12,900	4,800	5,500	11,900
Electrical/electronics	283,000	383,100	574,500	267,900	357,400	540,800
Men	281,400	357,400	555,500	266,500	350,200	523,200
Women	1,600	7,600	18,900	1,400	7,200	17,600
Mechanical	276,200	322,600	492,600	272,800	308,800	453,700
Men	273,900	316,000	478,600	270,600	302,000	440,100
Women	2,300	6,600	14,000	2,200	6,800	13,600
Other engineers	490,000	574,100	767,300	422,700	472,600	694,200
Men	480,900	550,600	729,600	414,200	451,600	658,900
Women	9,100	23,500	37,700	8,500	21,000	35,300

Note: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figures O-10, O-11, O-12, O-13 in Overview and figures 3-1 and 3-18

Science & Engineering Indicators—1987

Appendix table 3-2. Scientists and engineers as a percent of total U.S. workforce: 1976-86

Year	(Percent)
1976	2.4
1978	2.5
1980	2.6
1982	2.9
1984	3.3
1986	3.6

SOURCES: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming) *Economic Report of the President, 1987*, p. 282

See figure 3-1.

Science & Engineering Indicators—1987

Appendix table 3-3. Average annual percent increases in employment in science and engineering, and other economic variables: 1976-86

	1976-80	1980-86	1976-86
	Percent		
Scientists and engineers	4.6	7.9	6.6
Scientists	5.2	7.8	6.7
Engineers	4.3	7.9	6.4
U.S. employment	2.8	1.7	2.1
Real ¹ gross national product	3.0	2.4	2.6

¹ Gross national product measured in constant dollars, using the GNP deflator.

SOURCES: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming); *Economic Report of the President, 1987*, pp. 246, 282

See figure O-9 in Overview.

Science & Engineering Indicators—1987

Appendix table 3-4. Scientists and engineers, by field and primary work activity: 1976, 1986

Field	Primary work activity															
	Total		Research		Development		Management of R&D		Management—other than R&D		Teaching		Production inspection		Statistical work computing	
	1976	1986	1976	1986	1976	1986	1976	1986	1976	1986	1976	1986	1976	1986	1976	1986
Total, all S E fields	2,122,100	3,919,900	209,000	376,000	430,200	846,900	212,700	371,700	386,600	628,400	152,200	336,600	223,200	512,800	101,100	384,500
Total scientists	843,700	1,676,400	159,100	277,400	61,400	166,100	83,700	144,400	105,100	209,600	131,500	283,400	29,000	114,300	66,600	275,500
Physical scientists	154,900	264,900	48,900	68,900	21,300	43,600	26,800	42,300	13,400	19,300	16,200	44,200	1,600	29,600	3,100	6,500
Mathematical scientists ..	43,800	103,900	6,000	11,600	2,400	5,600	6,500	13,800	5,900	9,400	15,800	43,200	1,200	2,600	3,900	14,300
Computer specialists	116,000	437,200	1,800	13,800	25,400	87,300	8,400	27,200	15,600	35,500	3,500	16,300	3,700	15,400	38,200	206,000
Environmental scientists	46,600	97,300	17,100	28,900	3,400	6,200	5,900	7,300	6,000	11,300	2,400	8,200	2,600	20,600	2,000	6,300
Life scientists	198,200	340,500	55,600	108,100	6,700	14,600	18,400	28,700	38,400	51,900	28,100	58,700	14,000	35,600	3,200	9,100
Psychologists	103,700	172,800	6,700	15,300	1,200	2,300	4,200	7,100	12,300	25,500	20,900	38,200	1,800	2,600	1,100	2,800
Social scientists	180,500	269,800	23,000	30,800	1,000	6,400	13,500	17,900	13,500	56,900	44,600	74,600	4,100	7,900	15,100	30,500
Total engineers	1,278,300	2,243,500	49,800	98,700	368,900	680,800	128,900	227,300	256,500	418,700	20,700	53,100	179,800	398,500	34,600	108,900
Aeronautical/																
astronautical	55,700	104,200	5,500	9,600	20,100	39,700	13,800	20,600	4,900	9,400	1,000	2,400	4,400	10,800	1,800	5,700
Chemical	76,400	131,500	4,400	8,200	24,600	42,500	8,600	18,400	19,300	24,400	500	2,800	9,900	20,500	1,300	4,700
Civil	182,800	319,100	2,900	7,300	30,000	43,700	6,000	10,300	57,400	103,400	2,200	6,000	37,500	69,500	5,800	14,000
Electrical/electronics ...	267,900	540,800	11,800	27,300	101,400	209,700	38,300	76,900	40,100	74,600	4,400	12,700	27,400	81,100	6,300	22,700
Mechanical	272,800	453,700	8,400	16,800	106,700	187,300	28,700	48,500	56,300	79,800	5,300	8,900	29,700	67,200	3,100	11,800
Other engineers	422,700	694,200	16,800	29,500	86,100	157,900	33,500	52,600	78,500	127,100	7,300	20,300	70,900	149,400	16,300	50,000

Note: Detail may not add to total because of rounding

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figure 3-2.

Science & Engineering Indicators—1987

Appendix table 3-5. Scientists and engineers, by field and type of employer: 1976, 1986

Field	Type of employer							
	Total		Business Industry		Educational Institutions		Federal Government	
	1976	1986	1976	1986	1976	1986	1976	1986
Total, all S/E fields	2,122,100	3,919,900	1,312,500	2,589,300	267,800	572,700	211,100	334,200
Total scientists	843,700	1,676,400	357,900	797,900	230,200	481,800	105,200	153,500
Physical scientists	154,900	264,900	86,800	146,700	30,600	68,700	20,500	28,600
Mathematical scientists	43,800	103,900	12,100	35,600	19,500	52,800	9,300	10,700
Computer specialists	116,000	437,200	85,800	341,300	6,000	32,500	8,700	32,100
Environmental scientists	46,600	97,300	25,800	55,500	5,000	16,500	9,300	16,800
Life scientists	198,200	340,500	64,100	102,800	59,600	136,600	37,300	40,200
Psychologists	103,700	172,800	21,000	39,700	41,700	72,800	5,000	5,400
Social scientists	180,500	269,800	62,300	76,200	67,800	102,000	15,100	19,700
Total engineers	1,278,300	2,243,500	954,600	1,791,400	37,700	90,900	105,900	180,700
Aeronautical/astronautical	55,700	104,200	39,900	77,400	1,800	3,600	11,100	17,500
Chemical	76,400	131,500	68,400	114,200	900	5,400	2,600	6,600
Civil	182,800	319,100	85,100	195,700	5,300	8,800	21,500	31,600
Electrical/electronics	267,900	540,800	210,600	439,800	10,400	24,600	27,600	52,700
Mechanical	272,800	453,700	227,900	394,500	8,500	17,000	15,300	28,700
Other engineers	422,700	694,200	322,700	569,800	10,800	31,500	27,800	43,600

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figures 3-3, 3-4, 3-6, 3-7, and 3-11.

Science & Engineering Indicators—1987

Appendix table 3-6. Employed doctoral scientists and engineers, by field, gender, and type of employer: 1973, 1985

Field and gender	Type of employer							
	Total		Business Industry		Educational Institutions		Federal Government	
	1973	1985	1973	1985	1973	1985	1973	1985
Total, all S E fields	220,300	400,400	53,400	125,800	129,300	211,600	18,200	26,300
Men	203,400	341,900	52,000	112,855	103,300	177,300	17,200	23,600
Women	16,900	58,500	1,400	12,945	12,100	34,300	1,000	2,700
Total scientists	184,600	334,500	35,600	87,900	116,300	189,900	15,500	22,500
Men	167,800	277,500	34,300	75,785	104,300	156,000	14,500	19,900
Women	16,800	57,000	1,300	12,115	12,100	33,900	1,000	2,600
Physical scientists	48,500	67,500	19,700	30,300	22,000	29,700	4,100	4,000
Men	46,600	62,800	19,300	28,600	20,700	27,400	4,000	3,700
Women	1,900	4,700	300	1,700	1,300	2,300	100	300
Mathematical scientists	12,100	16,800	900	1,900	10,500	13,600	500	900
Men	11,400	15,200	800	1,700	9,800	12,400	500	800
Women	800	1,600	(¹)	200	700	1,200	(¹)	100
Computer specialists	2,700	15,000	1,000	8,400	1,400	5,300	100	700
Men	2,600	13,400	1,000	7,400	1,300	4,800	100	701
Women	100	1,600	(¹)	1,000	(¹)	500	(¹)	(¹)
Environmental scientists	10,300	17,200	2,200	5,300	5,200	7,200	2,000	3,300
Men	10,100	16,100	2,200	5,000	5,000	(6,200)	1,900	3,100
Women	300	1,100	(¹)	300	200	13,400	(¹)	200
Life scientists	56,700	101,800	7,100	19,200	38,200	61,800	5,800	8,000
Men	50,600	81,800	6,800	16,600	33,700	54,300	5,400	6,900
Women	6,100	20,000	300	2,600	4,600	7,500	500	1,100
Psychologists	24,800	52,100	3,100	15,500	15,000	24,500	1,200	1,000
Men	20,000	35,100	2,600	10,400	12,200	19,400	1,000	800
Women	4,800	17,000	500	5,100	2,900	5,100	200	200
Social scientists	29,400	64,000	1,700	7,400	24,000	43,800	1,700	4,600
Men	26,500	52,200	1,600	6,200	21,600	35,500	1,600	3,900
Women	2,900	11,800	100	1,200	2,400	8,300	100	700
Total engineers	35,800	65,900	17,800	37,900	13,000	21,700	2,700	3,800
Men	35,600	64,400	17,700	37,100	13,000	21,200	2,700	3,700
Women	100	1,500	100	800	100	500	(¹)	100
Aeronautical/astronautical	1,700	3,800	600	2,100	400	700	300	600
Men	1,700	3,700	600	2,000	400	701	300	601
Women	(¹)	100	(¹)	100	(¹)	(¹)	(¹)	(¹)
Chemical	4,500	7,100	3,200	5,100	1,000	1,800	100	200
Men	4,500	7,000	3,200	5,000	1,000	1,801	100	201
Women	(¹)	100	(¹)	100	(¹)	(¹)	(¹)	(¹)
Civil	3,100	6,400	900	2,400	1,700	3,400	200	300
Men	3,100	6,300	900	2,401	1,700	3,401	200	301
Women	(¹)	100	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Electrical/electronics	7,100	14,200	3,400	8,600	2,800	4,700	500	800
Men	7,100	13,900	3,400	8,400	2,800	4,600	500	801
Women	(¹)	300	(¹)	200	(¹)	100	(¹)	(¹)
Materials	4,500	7,300	2,700	4,800	1,200	1,800	400	400
Men	4,400	7,100	2,700	4,600	1,200	1,801	300	401
Women	(¹)	200	(¹)	200	(¹)	(¹)	(¹)	(¹)
Mechanical	3,300	6,600	1,400	3,100	1,600	9,000	200	300
Men	3,300	6,500	1,400	3,101	1,600	9,001	200	301
Women	(¹)	100	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Nuclear	1,300	2,400	700	1,500	300	500	200	100
Men	1,300	2,401	700	1,501	300	501	200	101
Women	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Systems design	2,000	3,700	1,000	2,500	600	800	200	100
Men	1,900	3,500	1,000	2,400	600	801	200	101
Women	(¹)	200	(¹)	100	(¹)	(¹)	(¹)	(¹)
Other engineers	8,600	14,300	3,900	7,800	3,300	5,000	800	1,000
Men	8,500	10,800	3,900	7,600	3,300	4,900	800	1,001
Women	(¹)	10,800	(¹)	200	(¹)	100	(¹)	(¹)

¹ Too few cases to estimateSOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1985*

See figure 3-5.

Science & Engineering Indicators—1987

Appendix table 3-7. Proportion of scientists and engineers employed in industry by sector and field: 1977, 1986

Field	Nonmanufacturing		Manufacturing	
	1977	1986	1977	1986
	Percent			
All S/E's	43.3	44.9	56.7	55.1
All Scientists	56.5	66.3	43.5	33.7
Computer specialists	68.9	71.2	31.1	28.8
Life scientists	20.2	40.7	79.8	59.3
Mathematical scientists	70.0	76.6	30.0	23.4
Physical scientists	32.8	45.7	67.2	54.3
Social scientists	95.8	97.5	4.2	2.5
All Engineers	38.9	36.8	61.1	63.2
Aeronautical/astronautical	13.5	9.9	86.5	90.1
Chemical	28.3	23.3	71.7	76.8
Civil	91.6	91.0	8.4	9.0
Electrical/electronics	41.6	34.1	58.4	65.9
Industrial	13.4	11.1	86.6	88.9
Mechanical	37.2	30.0	62.8	70.0
Other	35.7	40.8	64.4	59.2

SOURCE: National Science Foundation, Division of Science Resources Studies, Employment Studies Group
See figures 3-8 and 3-9. Science & Engineering Indicators—1987

Appendix table 3-8. Technicians employed in industry by field and sector: 1977, 1986

Field	Total		Non-manufacturing		Manufacturing	
	1977	1986	1977	1986	1977	1986
	Thousands					
All Technicians	929.4	1550.1	474.5	954.3	454.9	595.8
Computer Programmers	144.2	363.3	88.7	277.5	55.5	85.8
Drafters	236.5	321.2	132.3	191.4	104.2	129.8
Electrical/Electronics engineering ...	241.9	374.5	135.1	236.4	106.8	138.1
Mechanical engineering	35.4	60.1	4	17.4	31.4	42.7
Other Engineering	183	293.5	95.3	184.5	87.7	109
Science	88.4	137.5	19.1	47.1	69.3	90.4

Note: Nonmanufacturing industries include mining, construction, finance, insurance, real estate, services, communications and utilities, wholesale trade, and retail trade.

SOURCE: National Science Foundation, Division of Science Resources Studies, Employment Studies Group
See figure 3-10. Science & Engineering Indicators—1987

Appendix table 3-9. Percent of recent science and engineering (S/E) degree recipients employed in S/E jobs by degree and field: 1976, 1986

Field	Bachelor's		Master's	
	1976	1986	1976	1986
	Percent			
Total	44.7	63.8	77.4	84.3
Physical Sciences	58.9	68.0	67.5	85.7
Mathematics	45.9	73.6	61.5	89.7
Computer Sciences	90.0	89.2	85.4	90.0
Engineering	83.4	89.1	93.1	94.6
Life Sciences	49.7	56.7	75.9	80.6
Social Sciences	20.7	30.5	66.7	55.8

Note: Individuals enrolled full time in graduate school are excluded. Data for 1976 include 1974 and 1975 S/E graduates. Data for 1986 include 1984 and 1985 S/E graduates.

SOURCE: National Science Foundation, *Characteristics of Recent Science/Engineering Graduates: 1986* (forthcoming)

See figure 3-12.

Science & Engineering Indicators—1987

Appendix table 3-10. Science and engineering (S/E) degree recipients working as computer specialists in 1986, by field and year of degree

Field	Bachelor's		Master's	
	1984	1985	1984	1985
Total	35,600	41,900	8,000	8,800
Physical Sciences	700	200	100	100
Mathematics	3,900	3,600	400	400
Computer Sciences	24,200	29,800	6,000	6,800
Engineering	3,700	3,100	1,200	1,100
Environmental Sciences	100	100	100	100
Life Sciences	400	400	(¹)	100
Social Sciences	1,900	4,000	200	200
Psychology	600	600	(¹)	100

¹ Too few cases to report.

Note: Detail may not add to totals due to rounding.

SOURCE: National Science Foundation, *Characteristics of Recent Science Engineering Graduates: 1986* (forthcoming)

See figure 3-13.

Science & Engineering Indicators—1987

Appendix table 3-11. Employment status of doctoral scientists and engineers, by field and gender: 1973, 1981, 1985

Field and gender	Total employed			Employed in S E		
	1973	1981	1985	1973	1981	1985
Total, all S E fields	220,300	344,000	400,400	208,300	314,500	365,500
Men	203,400	303,000	341,900	192,600	277,800	313,000
Women	16,900	41,000	58,500	15,700	36,800	52,500
Total scientists	184,600	286,900	334,500	173,800	261,400	304,100
Men	167,800	246,700	277,500	158,300	225,400	253,000
Women	16,800	40,200	57,000	15,500	36,000	51,100
Physical scientists	48,500	63,100	67,500	45,100	57,100	61,300
Men	46,500	59,300	62,800	43,400	53,800	57,100
Women	1,900	3,800	4,700	1,700	3,300	4,200
Mathematical scientists	12,100	15,600	16,800	11,800	14,100	15,500
Men	11,400	14,300	15,200	11,100	12,900	14,100
Women	800	1,300	1,600	700	1,200	1,400
Computer specialists	2,700	9,100	15,000	2,700	9,000	14,800
Men	2,600	8,400	13,400	2,600	8,300	13,200
Women	100	700	1,600	100	700	1,600
Environmental scientists	10,300	15,900	17,300	10,100	15,300	16,700
Men	10,100	15,100	16,200	9,900	14,500	15,600
Women	300	900	1,100	300	800	1,000
Life scientists	56,700	84,900	101,800	54,800	80,700	96,700
Men	50,600	71,600	82,100	49,000	68,300	78,200
Women	6,100	13,300	19,700	5,800	12,500	18,500
Psychologists	24,800	42,800	52,200	23,500	39,400	48,000
Men	20,000	31,100	35,600	19,000	28,700	32,600
Women	4,800	11,700	16,600	4,500	10,600	15,400
Social scientists	29,400	55,500	64,000	25,900	45,800	51,100
Men	26,500	47,000	52,200	23,400	38,900	42,200
Women	2,900	8,600	11,800	2,500	6,900	8,900
Total engineers	35,800	57,000	65,900	34,400	53,200	61,500
Men	35,600	56,300	64,400	34,300	52,400	60,000
Women	100	800	1,500	100	700	1,400
Aeronautical/astronautical	1,700	2,500	3,800	1,600	2,200	3,600
Men	1,700	2,500	3,700	1,600	2,200	3,500
Women	(¹)	(¹)	100	(¹)	(¹)	100
Chemical	4,500	7,100	7,100	4,200	6,400	6,300
Men	4,500	7,100	7,000	4,200	6,300	6,200
Women	(¹)	100	100	(¹)	100	100
Civil	3,100	6,100	6,400	3,000	5,500	5,900
Men	3,100	6,000	6,300	3,000	5,400	5,800
Women	(¹)	100	100	(¹)	100	100
Electrical/electronics	7,100	10,600	14,200	6,800	10,000	13,500
Men	7,000	10,500	13,900	6,800	9,900	13,200
Women	(¹)	100	300	(¹)	100	300
Mechanical	3,300	5,400	6,600	3,100	5,000	6,100
Men	3,300	5,300	6,500	3,100	4,900	6,100
Women	(¹)	(¹)	100	(¹)	(¹)	(¹)
Nuclear	1,300	2,100	2,400	1,200	2,000	2,200
Men	1,300	2,000	2,300	1,200	2,000	2,200
Women	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Other engineers	15,000	23,200	25,300	14,500	22,000	23,900
Men	14,900	22,800	24,500	14,500	21,700	23,100
Women	100	400	800	100	400	800

¹ Too few cases to estimate

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States* (biennial series)

See figures 3-14, 3-15, 3-16, and 3-19

Science & Engineering Indicators—1987

Appendix table 3-12. Employed doctoral scientists and engineers, by field, gender, and primary work activity: 1973, 1985

Field and gender	Primary work activity											
	Total		Research		Development		Management of R&D		Management other than R&D		Teaching	
	1973	1985	1973	1985	1973	1985	1973	1985	1973	1985	1973	1985
Total, all S/E fields	220,300	400,400	63,000	132,500	8,500	22,000	26,200	35,000	13,200	34,700	79,900	111,700
Men	203,400	341,900	58,500	116,000	8,400	20,600	25,500	32,900	12,500	29,700	72,500	94,100
Women	16,900	58,500	4,500	16,500	200	1,400	700	2,100	800	5,000	7,500	17,600
Total scientists	184,600	334,500	54,700	106,700	3,500	11,200	19,300	24,000	11,000	29,200	71,100	99,200
Men	167,800	277,500	50,200	90,900	3,400	10,000	18,600	22,100	10,200	24,300	63,600	81,800
Women	16,800	57,000	4,500	15,800	100	1,200	700	1,900	800	4,900	7,400	17,400
Physical scientists	48,500	67,500	18,000	29,900	1,900	3,600	7,700	9,300	2,200	3,600	14,300	15,200
Men	46,600	62,800	17,400	27,900	1,900	3,400	7,600	9,000	2,100	3,400	13,400	13,900
Women	1,900	4,700	600	2,000	(¹)	200	100	300	100	200	900	1,300
Mathematical scientists	12,100	16,800	2,500	4,000	200	600	400	400	500	1,300	8,000	9,400
Men	11,400	15,200	2,400	3,700	100	500	300	401	400	1,200	7,400	8,400
Women	800	1,600	100	300	(¹)	100	(¹)	(¹)	(¹)	100	600	1,000
Computer specialists	2,700	15,000	500	6,000	600	4,100	300	1,700	200	1,100	900	2,800
Men	2,600	13,400	500	5,400	500	3,700	300	1,500	200	1,000	900	2,600
Women	100	1,600	(¹)	600	(¹)	400	(¹)	200	(¹)	100	(¹)	200
Environmental scientists	10,300	17,200	3,500	6,800	100	300	1,400	2,000	600	1,400	3,100	3,400
Men	10,100	16,100	3,400	6,300	100	301	1,400	1,900	600	1,300	3,000	3,200
Women	300	1,100	100	500	(¹)	(¹)	(¹)	100	(¹)	100	100	200
Life scientists	56,700	101,800	22,800	44,600	400	1,700	6,600	7,300	2,600	8,300	17,800	22,400
Men	50,600	81,800	20,000	35,800	400	1,400	6,300	6,600	2,400	6,700	15,600	17,400
Women	6,100	20,000	2,800	8,800	(¹)	300	300	700	200	1,600	2,200	5,000
Psychologists	24,800	52,100	3,200	5,200	200	400	1,500	1,000	2,500	5,200	9,300	13,200
Men	20,000	35,100	2,700	3,700	100	300	1,400	700	2,200	3,800	7,500	9,400
Women	4,800	17,000	500	1,500	(¹)	100	100	300	400	1,400	1,800	3,800
Social scientists	29,400	64,000	4,200	10,100	200	400	1,400	2,100	2,500	8,300	17,700	32,800
Men	26,500	52,200	3,800	8,100	100	300	1,300	1,700	2,400	6,900	15,800	26,900
Women	2,900	11,800	400	2,000	(¹)	100	100	400	100	1,400	1,900	5,900
Total engineers	35,800	65,900	8,300	25,800	5,000	10,800	7,000	11,000	2,200	5,500	8,900	12,500
Men	35,600	64,400	8,200	25,100	4,900	10,500	6,900	10,800	2,200	5,400	8,800	12,200
Women	100	1,500	(¹)	700	(¹)	300	(¹)	200	(¹)	100	(¹)	300
Aeronautical/astronautical	1,700	3,800	400	1,900	100	800	600	900	100	200	300	300
Men	1,700	3,700	400	1,900	100	800	600	900	100	200	300	300
Women	(¹)	100	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Chemical	4,500	7,100	900	3,200	800	1,200	900	1,200	400	500	700	900
Men	4,500	7,000	900	3,100	800	1,200	900	1,200	400	500	700	900
Women	(¹)	100	(¹)	100	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Civil	3,100	6,400	400	1,400	200	500	300	500	300	700	1,300	2,200
Men	3,100	6,300	400	1,400	200	500	300	500	300	700	1,300	2,200
Women	(¹)	100	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Electrical/electronics	7,100	14,200	1,400	5,300	1,400	2,900	1,400	2,900	300	1,300	2,000	3,000
Men	7,000	13,900	1,400	5,100	1,400	2,800	1,300	2,900	300	1,300	2,000	2,900
Women	(¹)	300	(¹)	200	(¹)	100	(¹)	(¹)	(¹)	(¹)	(¹)	100
Materials	4,500	7,300	1,500	3,300	400	600	1,200	1,500	100	400	700	800
Men	4,400	7,100	1,500	3,200	400	600	1,200	1,400	100	400	700	800
Women	(¹)	200	(¹)	100	(¹)	(¹)	(¹)	100	(¹)	(¹)	(¹)	(¹)
Mechanical	3,300	6,600	600	2,500	500	1,300	400	900	200	500	1,300	2,000
Men	3,300	6,500	600	2,500	500	1,300	400	900	200	500	1,300	2,000
Women	(¹)	100	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Nuclear	1,300	2,400	200	1,100	200	500	300	300	100	300	200	100
Men	1,300	2,400	200	1,100	200	500	300	300	100	300	200	100
Women	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Systems engineers	2,000	3,700	400	1,900	300	1,100	300	600	100	200	400	400
Men	1,900	3,500	400	1,800	300	1,000	300	600	100	200	400	400
Women	(¹)	200	(¹)	100	(¹)	100	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)
Other engineers	8,600	14,300	2,400	5,400	1,000	1,800	1,700	2,100	600	1,400	1,900	2,600
Men	8,500	14,300	2,400	5,200	1,000	1,800	1,700	2,100	600	1,400	1,900	2,500
Women	(¹)	(¹)	(¹)	200	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	(¹)	100

¹ Too few cases to estimate

Note: Detail may not add to totals due to rounding

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States* (biennial series)

See figure 3-17.

Science & Engineering Indicators—1987

Appendix table 3-13. Selected employment characteristics of scientists and engineers, by field: 1986

Field	Labor force participation rate	Unemployment rate	S/E Employment rate	S/E Underemployment rate	S/E Underutilization rate
			Percent		
Total, all S/E fields	94.5	1.5	84.7	2.6	4.1
Total scientists	95.3	1.9	76.7	4.3	6.1
Physical scientists	93.6	1.4	91.9	1.9	3.3
Chemists	94.1	3.2	91.5	1.8	5.0
Physicists/astronomers	95.1	1.1	94.1	1.2	2.2
Other physical scientists	95.1	1.9	89.1	3.3	5.2
Mathematical scientists	94.6	1.3	79.3	3.3	4.6
Mathematicians	94.5	1.1	77.7	3.4	4.5
Statisticians	95.2	2.4	87.8	3.0	5.3
Computer specialists	98.5	0.8	77.7	2.5	3.3
Environmental scientists	94.5	4.4	87.4	5.6	9.7
Earth scientists	94.4	5.0	86.3	6.1	10.8
Oceanographers	92.4	0.1	97.9	0.7	0.8
Atmospheric scientists	96.0	1.5	88.8	3.5	4.9
Life scientists	93.0	2.1	82.7	4.7	6.7
Biological scientists	92.9	2.2	83.5	5.2	7.3
Agricultural scientists	93.3	2.5	78.3	5.1	7.5
Medical scientists	93.9	0.4	89.5	0.1	0.5
Psychologists	95.1	2.5	68.2	5.7	8.1
Social scientists	95.4	2.4	60.7	7.2	9.4
Economists	95.5	3.1	61.3	5.6	8.5
Sociologists/anthropologists	95.3	2.2	61.2	9.2	11.1
Other social scientists	95.4	1.3	59.9	7.7	9.4
Total Engineers	93.8	1.2	91.9	1.0	2.2
Aeronautical/astronautical	94.7	0.4	94.3	0.6	1.0
Chemical	89.1	2.6	83.2	1.9	4.5
Civil	92.3	1.7	92.1	1.2	2.9
Electrical/electronics	93.5	1.1	94.1	0.8	1.8
Industrial	96.1	1.1	82.2	1.2	2.3
Materials	94.0	1.7	88.3	0.9	2.6
Mechanical	91.2	1.3	92.1	1.1	2.4
Mining	93.7	2.2	86.1	1.6	3.8
Nuclear	97.8	1.0	97.5	0.4	1.4
Petroleum	95.3	3.4	92.9	2.0	5.4
Other engineers	98.3	0.7	92.7	0.8	1.5

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figures 3-20 and 3-21.

Science & Engineering Indicators—1987

Appendix table 3-14. Estimates and projections of the population by selected age group: 1950-2010

Year	Total population	Age (Years)	
		18-24	25-34
Thousands			
Estimates			
1950	152,271	16,075	24,036
1955	165,931	14,968	24,283
1960	180,671	16,128	22,919
1965	194,303	20,293	22,465
1970	205,052	24,712	25,323
1975	215,973	28,005	31,471
1980	227,704	30,347	37,593
Projections			
1985	238,631	28,739	41,788
1990	249,657	25,794	43,529
1995	259,559	23,702	40,520
2000	267,995	24,601	36,415
2005	275,667	26,981	35,009
2010	283,238	27,665	36,978

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Projections of the Population of the United States, by Age, Sex and Race: 1983-2080*, Series p-25, No. 952 (May 1984), table E, p. 7

See figure 3-23.

Science & Engineering Indicators—1987

Appendix table 3-15. Number of nonacademic scientists and engineers per 10,000 total labor force, by gender

Country	Labor force	Scientists and engineers			S/E per 10,000 labor force		
		Total	Men	Women	Total	Men	Women
France (1982)	23,525,120	387,860	346,020	41,840	165	147	18
West Germany (1985)	26,626,400	621,500	585,400	36,100	234	220	14
Japan (1985)	60,270,700	1,514,200	144,400	69,800	252	240	12
United Kingdom (1981)	25,405,590	653,140	583,330	69,810	257	230	27
United States (1984)	115,241,000	3,179,100	2,844,300	334,800	276	247	29
Scientists							
Country	Labor force	Scientists			Scientists per 10,000 labor force		
		Total	Men	Women	Total	Men	Women
France (1982)	23,525,120	139,980	107,100	32,880	60	46	14
West Germany (1985)	26,626,400	103,800	85,900	17,900	39	32	7
Japan (1985)	60,270,700	389,900	338,400	51,500	65	56	9
United Kingdom (1981)	25,405,590	287,690	223,830	63,860	113	88	25
United States (1984)	115,241,000	1,162,700	894,700	268,000	101	78	23
Engineers							
Country	Labor force	Engineers			Engineers per 10,000 labor force		
		Total	Men	Women	Total	Men	Women
France (1982)	23,525,120	247,880	238,920	8,960	105	102	4
West Germany (1985)	26,626,400	517,700	499,500	18,200	194	188	7
Japan (1985)	60,270,700	1,124,300	1,106,000	18,300	187	184	3
United Kingdom (1981)	25,405,590	365,450	359,500	5,950	144	142	2
United States (1984)	115,241,000	2,016,400	1,949,600	66,800	175	169	6

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987* (NSF 87-319)

See figure 3-24.

Science & Engineering Indicators—1987

Appendix table 3-16. Distribution of scientists and engineers in manufacturing industry, by occupation group

Country	Total	Scientists	Engineers		
			Civil	Electrical Electronic	Industrial Mechanical
			Percent		
United States (1985)	100.0	16.6	1.0	26.3	56.1
France (1982)	100.0	22.9	3.5	20.5	53.1
West Germany (1985)	100.0	18.0	3.2	21.9	56.8
Japan (1980)	100.0	18.1	1.6	24.5	55.9
United Kingdom (1981)	100.0	25.9	1.0	14.1	59.0

Note: Figures for all countries exclude scientists and engineers in academic positions. The Industrial Mechanical category includes all other engineers.

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987* (NSF 87-319)

See figure 3-25

Science & Engineering Indicators—1987

Appendix table 3-17. Scientists and engineers engaged in R&D as a proportion of the total labor force population, by country: 1965-86

Country	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.	
						Low Estimate	High Estimate
S/E's in R&D, per 10,000 labor force population							
1965	21.0	22.7	24.6	19.6	64.7	44.8	48.2
1966	29.2	22.4	26.4	NA	66.9	47.1	51.4
1967	25.3	24.9	27.8	NA	67.2	50.7	55.3
1968	26.4	26.2	31.1	20.8	68.0	53.5	58.8
1969	27.1	28.4	30.8	NA	66.7	56.5	62.1
1970	27.3	30.8	33.4	NA	64.1	58.1	64.0
1971	27.9	33.4	37.5	NA	60.7	62.9	69.2
1972	28.2	35.6	38.1	30.4	58.0	67.1	74.2
1973	28.5	37.1	42.5	NA	56.4	71.0	79.1
1974	28.9	37.8	44.9	NA	55.6	74.2	82.6
1975	29.4	38.6	47.9	31.1	55.3	77.6	86.7
1976	29.9	39.2	48.4	NA	54.8	79.1	88.5
1877	30.0	41.8	49.9	NA	55.7	80.4	90.2
1978	31.0	NA	49.4	33.3	56.5	82.2	92.5
1979	31.6	45.3	50.4	NA	57.7	83.6	94.5
1980	32.4	NA	53.6	NA	60.0	85.7	97.1
1981	36.3	46.5	55.6	35.8	62.0	88.1	100.0
1982	37.9	47.0	57.1	NA	62.8	91.1	103.7
1983	39.1	48.4	58.1	35.1	63.8	92.4	105.9
1984	41.2	49.1	62.4	34.2	65.1	94.6	108.8
1985	NA	NA	63.2	32.8	67.4	96.9	111.6
1986	NA	NA	NA	NA	69.0	NA	NA

Note: NA = Not Available.

Note: Table includes all scientists and engineers engaged in research and development on a full-time basis except Japan, whose data include persons primarily employed in research and development, and the United Kingdom whose data include only the Government and industry sectors. The figures for West Germany increased in 1979 in part because of increased coverage of small and medium enterprises not surveyed in 1977. The figures for France increased in 1981 in part due to a re-evaluation of university research efforts.

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987* (NSF 87-319)

See figure O-7 in Overview.

Science & Engineering Indicators—1987

Appendix table 3-18. Distribution of scientists and engineers, by sector, for selected countries

Country	Total	Manufacturing & mining	Construction	Services	Government
		Percent			
United States (1985)	100.0	51.0	2.5	36.5	10.0
France (1982)	100.0	44.4	7.3	17.9	30.4
West Germany (1985)	100.0	48.4	8.7	31.7	11.2
Japan (1985)	100.0	33.0	17.4	45.8	3.7
United Kingdom (1981)	100.0	49.2	5.7	36.1	8.9

Note: Figures for all countries exclude scientists and engineers in academic positions.

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987*, (NSF 87-319)

See figure 3-26

Science & Engineering Indicators—1987

Appendix table 3-19. Scientists and engineers engaged in research and development, by country: 1965-86

Country	France	West Germany	Japan	United Kingdom	United States	U.S.S.R.	
						Low Estimate	High Estimate
1965	42.8	61.0	117.6	49.9	494.6	521.8	561.4
1966	60.0	60.0	128.9	NA	521.1	556.5	607.6
1967	52.4	64.5	138.7	NA	534.4	607.8	662.6
1968	54.7	68.0	157.6	52.8	550.4	650.8	715.2
1969	57.2	74.9	157.1	NA	553.2	698.8	767.5
1970	58.5	82.5	172.0	NA	544.2	730.1	803.6
1971	60.1	90.2	194.3	NA	523.8	804.2	884.2
1972	61.2	96.0	198.1	76.7	515.3	872.3	964.5
1973	62.7	101.0	226.6	NA	514.8	938.9	1,045.1
1974	64.1	102.5	238.2	NA	520.8	997.0	1,110.6
1975	65.3	103.7	255.2	80.5	527.7	1,060.7	1,184.3
1976	67.0	104.5	260.2	NA	535.6	1,098.0	1,229.1
1877	68.0	111.0	272.0	NA	561.0	1,134.2	1,272.8
1978	70.9	NA	273.1	87.7	587.0	1,178.2	1,326.0
1979	72.9	122.0	281.9	NA	614.8	1,217.8	1,376.5
1980	74.9	NA	302.6	NA	651.7	1,262.4	1,430.4
1981	85.5	127.4	317.5	95.7	683.7	1,311.8	1,489.4
1982	90.1	129.0	329.7	NA	702.8	1,368.6	1,558.0
1983	92.7	133.1	342.2	94.1	722.9	1,399.0	1,603.0
1984	98.2	135.0	370.0	92.3	750.7	1,441.8	1,658.5
1985	NA	NA	381.3	90.0	790.0	1,485.3	1,710.5
1986	NA	NA	406.0	NA	825.0	NA	NA

Note: NA = Not Available.

Note: Table includes all scientists and engineers engaged in research and development on a full-time basis except Japan, whose data include persons primarily employed in research and development, and the United Kingdom whose data include only the Government and industry sectors. The figures for West Germany increased in 1979 in part because of increased coverage of small and medium enterprises not surveyed in 1977. The figures for France increased in 1981 in part due to a re-evaluation of university research efforts.

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987* (NSF 87-319)

See figure 3-27.

Science & Engineering Indicators—1987

Appendix table 3-20. Distribution of scientists and engineers, by age group, for selected countries

Country	Total	Under 35	35-54	55 +
		Percent		
United States (1984)	100.0	27.6	53.3	19.0
France (1982)	100.0	29.6	58.4	12.1
West Germany (1985)	100.0	30.3	56.0	13.6
Japan (1985)	100.0	48.4	44.9	6.7
United Kingdom (1981)	100.0	45.2	42.4	12.5

Note: Figures for all countries exclude scientists and engineers in academic positions.

SOURCE: National Science Foundation, *International Science and Technology Data Update 1987* (NSF 87-319)

See figure 3-28.

Science & Engineering Indicators—1987

**Appendix table 3-21. Employment status of scientists and engineers,
by field and race: 1976, 1980, 1986**

Field and race	Total Employed			Employed in S/E		
	1976	1980	1986	1976	1980	1986
Total, all S/E fields	2,331,200	2,860,400	4,626,500	2,122,100	2,542,700	3,919,900
White	2,141,900	2,644,900	4,190,400	1,949,700	2,349,700	3,556,200
Black	38,100	57,600	114,900	34,900	50,900	87,900
Asian	106,600	121,000	226,800	98,500	112,000	199,000
Other	44,600	37,000	94,400	38,900	30,100	76,800
Total scientists	959,500	1,184,500	2,186,300	843,800	1,032,800	1,676,400
White	870,900	1,097,000	1,973,100	764,200	957,900	1,521,000
Black	21,400	30,500	73,700	19,400	26,000	50,600
Asian	48,500	41,500	94,000	43,100	37,500	72,300
Other	18,700	15,400	45,500	17,100	11,400	32,500
Physical scientists	188,900	215,200	288,400	154,900	166,300	264,900
White	172,400	201,200	261,800	141,200	155,600	240,400
Black	3,200	3,400	6,200	2,400	2,400	5,400
Asian	7,600	8,800	15,400	6,400	7,100	14,500
Other	5,700	1,800	5,000	4,900	1,200	4,600
Mathematical scientists	48,600	64,300	131,000	43,800	57,300	103,900
White	44,200	59,200	115,500	39,400	52,600	91,300
Black	2,600	2,900	6,800	2,500	2,500	6,100
Asian	1,600	2,100	5,900	1,700	2,100	4,200
Other	200	200	2,800	200	200	2,300
Computer specialists	119,000	207,800	562,600	116,000	196,700	437,200
White	110,700	192,000	497,100	108,000	181,500	388,200
Black	1,600	4,700	18,900	1,500	4,300	13,200
Asian	4,000	9,900	36,100	3,900	9,700	27,600
Other	2,700	1,300	10,500	2,600	1,200	8,200
Environmental scientists	54,800	77,600	111,300	46,600	63,100	97,300
White	48,300	70,000	105,800	40,700	57,700	93,600
Black	2,000	700	1,000	1,800	800	400
Asian	3,200	2,500	2,100	2,900	2,000	1,900
Other	1,200	4,400	2,400	1,200	2,700	1,400
Life scientists	213,500	287,500	411,800	198,200	267,300	340,500
White	200,700	270,300	377,900	186,100	250,700	313,300
Black	4,900	6,700	8,800	4,700	6,400	7,100
Asian	5,300	7,100	15,000	5,400	6,900	12,900
Other	2,500	3,400	10,100	2,000	3,400	7,200
Psychologists	112,500	128,100	253,500	103,700	112,500	172,800
White	105,100	121,600	234,100	97,100	107,400	161,800
Black	3,800	3,800	9,100	3,700	3,400	6,000
Asian	1,000	1,200	5,200	700	1,000	1,400
Other	2,600	1,500	5,100	2,100	800	3,600
Social scientists	222,300	204,000	427,800	180,500	169,700	259,800
White	189,400	182,800	380,800	151,600	152,600	232,600
Black	3,300	8,300	22,900	2,900	6,400	12,300
Asian	25,800	10,000	14,200	22,100	8,700	9,700
Other	3,800	2,900	9,900	3,900	2,000	5,200

(continued)

Appendix table 3-21. (Continued)

Field and race	Total Employed			Employed in S/E		
	1976	1980	1986	1976	1980	1986
Total engineers	1,371,700	1,675,900	2,440,100	1,278,300	1,509,900	2,243,500
White	1,271,000	1,547,800	2,217,300	1,185,500	1,391,700	2,035,200
Black	16,700	27,000	41,300	15,500	24,900	37,300
Asian	58,100	79,500	132,800	55,400	76,600	126,700
Other	25,900	21,600	48,700	21,900	18,700	44,300
Aeronautical/astronautical	56,800	69,500	110,500	55,700	65,000	104,200
White	54,100	65,000	100,800	52,900	60,500	94,900
Black	300	1,100	1,600	300	1,200	1,400
Asian	1,600	2,200	6,600	1,700	2,100	6,500
Other	700	1,200	1,500	700	1,200	1,400
Chemical	77,500	94,500	149,000	76,400	89,000	131,500
White	72,200	86,400	133,900	71,100	81,300	119,200
Black	1,500	800	2,000	1,500	400	900
Asian	2,400	5,800	10,100	2,400	5,700	9,200
Other	1,400	1,500	3,000	1,400	1,500	2,200
Civil	188,200	232,100	346,300	182,800	217,000	319,100
White	165,700	209,100	308,600	162,500	194,900	284,300
Black	1,600	3,900	5,200	1,800	3,800	4,800
Asian	14,800	16,000	24,500	14,800	15,200	23,300
Other	6,100	3,100	8,000	3,700	3,100	6,700
Electrical/electronics	283,000	383,100	574,500	267,900	357,400	540,800
White	262,500	346,500	512,500	248,800	323,600	481,800
Black	2,900	8,100	11,900	2,600	7,500	11,000
Asian	13,800	23,300	37,900	12,700	22,100	36,000
Other	3,800	5,100	12,200	3,800	4,200	12,000
Mechanical	276,200	322,600	492,600	272,800	308,800	453,700
White	258,700	302,000	452,600	255,300	288,900	416,000
Black	2,400	2,700	6,700	2,200	2,500	6,400
Asian	9,700	13,900	24,600	9,600	13,600	23,400
Other	5,500	3,900	8,700	5,700	3,900	7,900
Other engineers	490,000	574,100	767,200	422,700	472,600	694,200
White	457,800	538,700	708,900	394,900	442,400	639,000
Black	8,000	10,300	13,900	7,000	9,400	12,800
Asian	15,800	18,300	29,100	14,300	15,900	28,300
Other	8,500	6,700	15,300	6,500	4,900	14,100

Note: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figure O-14 in Overview.

Science & Engineering Indicators—1987

Appendix table 3-22. Employment status of Hispanic scientists and engineers, by field: 1986

Field	Total employed	Employed in S/E
Total, all S/E fields	93,400	74,900
Total scientists	46,100	31,200
Physical scientists	4,800	4,600
Mathematical scientists	3,100	2,600
Computer specialists	9,300	6,100
Environmental scientists	1,800	1,600
Life scientists	9,900	7,100
Psychologists	5,900	2,700
Social scientists	11,400	6,600
Total engineers	47,200	43,700
Aeronautical/astronautical	1,500	1,400
Chemical	2,700	2,500
Civil	7,300	7,100
Electrical/electronics	12,200	11,400
Industrial	2,500	2,300
Materials	400	400
Mechanical	9,000	7,900
Mining	100	100
Nuclear	100	100
Petroleum	700	700
Other engineers	10,700	9,900

Note: Detail may not add to total because of rounding.

SOURCE: National Science Foundation, *U.S. Scientists and Engineers: 1986* (forthcoming)

See figure O-14 in Overview. Science & Engineering Indicators—1987

Appendix table 3-23. First university degrees by major field of study and country: 1984 and 1985

Academic fields	United States (1985)		Japan (1985)		West Germany (1984)		United Kingdom (1984)		France ¹ (1984)		Soviet Union ² (1985)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
All fields	990,877	100.0	373,302	100.0	57,153	100.0	73,841	100.0	46,248	100.0	858,900	100.0
Natural sciences and engineering	213,918	21.6	97,544	26.1	19,735	34.5	29,443	39.9	22,050	47.7	456,935	53.2
Natural sciences	120,168	12.1	12,698	3.4	9,429	16.5	17,400	23.6	9,350	20.2	52,395	6.1
Engineering	77,871	7.9	71,396	19.1	8,068	14.1	10,577	14.3	12,700	27.5	334,970	39.0
Agriculture	15,879	1.6	13,450	3.6	2,238	3.9	1,466	2.0	(³)	(³)	69,570	8.1
Other	776,959	78.4	275,758	73.9	37,418	65.5	44,398	60.1	24,198	52.3	401,965	46.8

¹ Data for France are based on maîtrise degrees and engineering degrees. French engineering degrees are equivalent to U.S. master's degree.

² Figures for the Soviet Union are estimates made to approximate the U.S. definitions.

³ Included in natural sciences.

NOTE: Percents are based on unrounded figures. Natural sciences include physical sciences, biological sciences and mathematics.

Source: National Science Foundation, International Science and Technology Data Update 1987 (NSF 87-319)

See figure O-8 in Overview.

Science & Engineering Indicators—1987

Appendix table 4-1. National expenditures on research and development,¹ by source of funds, selected countries: 1970-86

Country and source	1970	1975	1979	1981	1983	1984	1985	1986
Millions national currency								
United States	26,134	35,213	54,933	71,840	87,204	97,639	107,462	116,793
Domestic sources	26,134	35,213	54,933	71,840	87,204	97,639	107,462	116,793
Business Enterprises	10,444	15,820	26,081	35,944	43,515	49,066	52,569	55,699
Government	14,892	18,109	26,815	33,405	40,671	45,341	51,330	57,219
Non-profit	337	535	837	971	1,137	1,208	1,304	1,375
Universities	461	749	1,200	1,520	1,881	2,024	2,259	2,500
From abroad	NA	NA	NA	NA	NA	NA	NA	NA
Japan	1,355,505	2,974,573	4,583,630	5,982,356	7,180,782	7,893,931	8,890,299	NA
Domestic sources	1,342,048	2,915,853	4,577,044	5,975,816	7,172,561	7,886,341	NA	NA
Business Enterprises	792,970	1,715,734	2,697,945	3,726,055	4,678,482	5,278,564	6,125,416	NA
Government	392,012	882,853	1,347,983	1,611,686	1,720,815	1,777,349	1,866,963	NA
Non-profit	4,887	20,812	16,525	41,857	46,396	55,175	NA	NA
Universities	152,179	296,454	514,591	596,218	726,868	775,253	NA	NA
From abroad	1,060	3,054	3,586	6,143	8,220	7,590	NA	NA
West Germany	13,903	22,968	33,457	37,703	42,512	44,200	49,000	53,400
Domestic sources	13,752	22,576	32,843	37,340	42,030	NA	NA	NA
Business Enterprises	7,419	11,514	18,540	21,860	25,144	NA	29,841	NA
Government	6,311	10,898	14,211	15,328	16,732	NA	18,424	NA
Non-profit	23	164	92	152	154	NA	NA	NA
Universities	0	0	0	0	0	NA	NA	NA
From abroad	151	392	613	363	482	NA	NA	NA
France	14,955	26,203	44,123	62,471	84,671	96,198	105,917	117,000
Domestic sources	14,775	24,747	41,830	59,277	81,658	92,098	NA	NA
Business Enterprises	5,465	10,235	19,019	25,562	35,525	39,200	43,850	NA
Government	8,985	14,467	18,655	25,209	34,968	51,658	56,136	NA
Non-profit	21	30	267	233	363	NA	NA	NA
Universities	305	15	3,889	120	194	NA	NA	NA
From abroad	180	410	2,293	3,194	3,013	4,100	NA	NA
United Kingdom ³	1,069	2,151	3,510	6,134	6,820	NA	8,150	NA
Domestic sources	1,019	2,038	3,281	5,692	NA	NA	NA	NA
Business Enterprises	453	823	1,484	2,529	2,869	NA	3,757	NA
Government	548	1,176	1,717	3,008	3,424	NA	3,537	NA
Non-profit	11	25	50	97	139	NA	NA	NA
Universities	7	15	30	58	36	NA	NA	NA
From abroad	47	105	212	411	348	NA	NA	NA

(continued)

Appendix table 4-1. (Continued)

Country and source	1970	1975	1979	1981	1983	1984	1985	1986
Millions U.S. 1982 constant dollars ²								
United States	62,179	59,371	69,916	76,458	83,963	90,633	96,665	102,405
Domestic sources	62,179	59,371	69,916	76,458	83,963	90,633	96,665	102,405
Business Enterprises	24,849	26,673	33,195	38,255	41,898	45,545	47,287	48,837
Government	35,432	30,533	34,129	35,552	39,159	42,088	46,173	50,170
Non-profit	802	902	1,065	1,033	1,095	1,121	1,173	1,206
Universities	1,097	1,263	1,527	1,618	1,811	1,879	2,032	2,192
From abroad	NA	NA	NA	NA	NA	NA	NA	NA
Japan	12,442	16,673	20,985	25,570	29,904	32,480	36,023	NA
Domestic sources	12,319	16,344	20,955	25,542	29,870	32,449	NA	NA
Business Enterprises	7,279	9,617	12,352	15,926	19,484	21,719	24,820	NA
Government	3,598	4,949	6,171	6,889	7,166	7,313	7,565	NA
Non-profit	45	117	76	179	193	227	NA	NA
Universities	1,397	1,662	2,356	2,548	3,027	3,190	NA	NA
From abroad	10	17	16	26	34	31	NA	NA
West Germany	9,880	11,894	14,858	15,357	16,071	16,385	17,773	18,789
Domestic sources	9,773	11,691	14,585	15,209	15,888	NA	NA	NA
Business Enterprises	5,272	5,962	8,233	8,904	9,505	NA	10,824	NA
Government	4,485	5,643	6,311	6,243	6,325	NA	6,683	NA
Non-profit	16	85	41	62	58	NA	NA	NA
Universities	0	0	0	0	0	NA	NA	NA
From abroad	107	203	272	148	182	NA	NA	NA
France	7,091	8,144	9,448	10,781	11,919	12,603	13,123	13,850
Domestic sources	7,006	7,691	8,957	10,230	11,495	12,066	NA	NA
Business Enterprises	2,591	3,181	4,072	4,411	5,001	5,136	5,433	NA
Government	4,260	4,496	3,994	4,350	4,922	6,768	6,955	NA
Non-profit	10	9	57	40	51	NA	NA	NA
Universities	145	5	833	21	27	NA	NA	NA
From abroad	85	127	491	551	424	537	NA	NA
United Kingdom ³	8,726	9,496	9,288	12,155	11,946	NA	12,930	NA
Domestic sources	8,317	8,997	8,682	11,278	NA	NA	NA	NA
Business Enterprises	3,701	3,631	3,926	5,011	5,025	NA	5,961	NA
Government	4,473	5,191	4,544	5,959	5,997	NA	5,611	NA
Non-profit	90	109	133	192	243	NA	NA	NA
Universities	54	65	79	115	63	NA	NA	NA
From abroad	380	464	562	814	610	NA	NA	NA

Note: NA = not available.

¹ Gross expenditures for performance of R&D including associated capital expenditures, except for the United States where total capital expenditure data are not available.

² Data are deflated using the implicit GDP price deflator, except for the United States, for which the GNP deflator is used. Deflated data are transformed into dollars using the 1975 purchasing power parity.

³ United Kingdom data for 1970 are for fiscal year 1969/70, and 1979 for fiscal year 1978/79.

SOURCES: OECD, *Science and Technology Indicators Recent Results*, September, 1987; National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming); National Science Foundation, unpublished statistics

See figures O-1 and O-4 in Overview.

Science & Engineering Indicators—1987

Appendix table 4-2. National expenditures for performance of R&D¹ as a percent of gross national product (GNP),² by country: 1970-87

Year	France	West Germany	Japan	United Kingdom	United States	Soviet Union
National expenditures on R&D as a percent of GNP						
1970	1.91	2.06	1.85	2.07	2.57	3.28
1971	1.90	2.19	1.85	NA	2.42	3.46
1972	1.90	2.20	1.86	2.11	2.35	3.71
1973	1.76	2.09	1.90	NA	2.26	3.81
1974	1.79	2.13	1.97	NA	2.23	3.74
1975	1.80	2.22	1.96	2.19	2.20	3.78
1976	1.77	2.15	1.95	NA	2.19	3.61
1977	1.76	2.14	1.93	NA	2.15	3.54
1978	1.76	2.24	2.00	2.24	2.14	3.54
1979	1.81	2.40	2.09	NA	2.19	3.59
1980	1.84	2.42	2.22	NA	2.29	3.76
1981	2.01	2.44	2.38	2.41	2.35	3.75
1982	2.10	2.59	2.47	NA	2.51	3.68
1983	2.15	2.54	2.61	2.25	2.56	3.82
1984	2.25	2.52	2.61	NA	2.59	3.95
1985	2.31	2.67	2.77	2.42	2.69	3.74
1986	2.41	2.74	NA	NA	2.72	3.79
1987	NA	NA	NA	NA	2.77	NA
National expenditures on R&D national currency in millions						
1970	14,955	13,903	1,355,505	1,069	26,134	11,700
1971	16,621	16,527	1,532,372	NA	26,676	13,000
1972	18,277	18,212	1,791,879	1,350	28,477	14,400
1973	19,789	19,232	2,215,837	NA	30,718	15,700
1974	23,031	20,990	2,716,032	NA	32,864	16,500
1975	26,203	22,968	2,974,573	2,300	35,213	17,400
1976	29,774	24,150	3,320,288	NA	39,018	17,700
1977	33,185	25,733	3,651,319	NA	42,783	18,300
1978	37,671	28,900	4,045,864	3,680	48,129	19,300
1979	44,123	33,457	4,583,630	NA	54,933	20,200
1980	51,014	35,903	5,246,247	NA	62,593	22,300
1981	62,471	37,703	5,982,356	6,134	71,840	23,400
1982	74,836	41,300	6,528,701	NA	79,328	24,600
1983	84,671	42,512	7,180,782	6,820	87,204	25,700
1984	96,198	44,200	7,893,931	NA	97,639	27,600
1985	105,917	49,000	8,890,299	8,150	107,642	27,500
1986	117,000	53,400	NA	NA	116,793	29,000
1987	NA	NA	NA	NA	124,250	NA
Gross national product national currency in billions						
1970	782.0	676.0	73,128.0	51.6	1,015.5	356.2
1971	873.1	756.0	82,725.8	57.8	1,102.7	375.7
1972	961.3	827.2	96,424.0	63.9	1,212.8	388.6
1973	1,121.3	920.1	116,636.3	74.2	1,359.3	412.2
1974	1,284.4	986.9	138,044.6	84.3	1,472.8	441.0
1975	1,452.0	1,034.9	151,797.0	105.2	1,598.4	460.5
1976	1,677.8	1,125.0	170,290.0	125.7	1,782.8	490.0
1977	1,885.0	1,200.0	188,804.3	143.2	1,990.5	516.6
1978	2,141.0	1,290.7	202,708.0	164.6	2,249.7	545.1
1979	2,442.0	1,395.3	218,894.0	191.1	2,508.2	563.2
1980	2,765.0	1,484.2	235,834.0	229.5	2,732.0	593.1
1981	3,110.6	1,545.1	251,259.0	254.8	3,052.6	624.2
1982	3,567.0	1,597.1	263,984.0	278.1	3,166.0	667.8
1983	3,935.0	1,674.1	274,639.0	303.2	3,401.6	672.9
1984	4,277.2	1,756.9	303,019.8	322.7	3,774.7	699.3
1985	4,579.6	1,837.9	320,774.8	337.0	3,996.7	735.5
1986	4,857.2	1,949.0	330,712.7	NA	4,291.0	765.0
1987	NA	NA	NA	NA	4,491.3	NA

Note: NA = Not available.

Note: The latest data may be preliminary or estimates. The figures for West Germany increased in 1979 in part because of increased coverage of small and medium enterprises not surveyed prior to 1977.

¹ Gross expenditures for performance of R&D including associated capital expenditures except for the United States where total capital expenditure data are not available. U.S. estimates for the period 1972-80 show that the inclusion of capital expenditures would have an impact of less than one percent of the R&D GNP ratio.

² Gross domestic product is used for France.

SOURCES: GNP data: International Monetary Fund, *International Financial Statistics*, vol. 30 (May 1977), vol. 31 (May 1978), vol. 31 (August 1978), vol. 32 (January 1979), and vol. 33 (August 1980). U.S. Department of Commerce, *International Economic Indicators* (June 1984); international R&D expenditure data: OECD, *Science and Technology Indicators Recent Results, 1981-87*, September, 1987 and OECD, Science, Technology and Industry Indicators Division, unpublished statistics; Soviet Union: unpublished statistics provided by Robert Campbell, Indiana University; United States: Division of Science Resources Studies, National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming).

See figure O-2 in Overview.

Science & Engineering Indicators—1987

Appendix table 4-3. Estimated non-defense R&D expenditures¹ as a percent of gross national product (GNP),² by country: 1971-87

Year	France	West Germany	Japan	United Kingdom	United States
Estimated non-defense R&D expenditures as a percent of GNP					
1971	NA	2.03	1.84	NA	1.65
1972	1.58	2.08	1.84	1.56	1.60
1973	1.38	1.94	1.89	NA	1.58
1974	1.43	1.98	1.96	NA	1.63
1975	1.46	2.08	1.95	1.55	1.63
1976	1.44	2.01	1.94	NA	1.62
1977	1.44	2.01	1.92	NA	1.61
1978	1.41	2.10	1.98	1.61	1.63
1979	1.42	2.27	2.08	NA	1.69
1980	1.43	2.30	2.21	NA	1.79
1981	1.50	2.34	2.37	1.72	1.81
1982	1.63	2.48	2.46	NA	1.88
1983	1.69	2.43	2.60	1.60	1.87
1984	1.76	2.41	2.59	NA	1.86
1985	1.85	2.53	2.75	1.71	1.86
1986	1.94	2.60	NA	NA	1.85
1987	NA	NA	NA	NA	1.88
Estimated non-defense R&D expenditures national currency in billions					
1971	NA	15.3	1,520.1	NA	18.1
1972	15.2	17.2	1,777.8	1.0	19.4
1973	15.4	17.9	2,200.2	NA	21.5
1974	18.4	19.6	2,699.8	NA	24.0
1975	21.2	21.6	2,957.5	1.6	26.1
1976	24.2	22.7	3,301.4	NA	28.9
1977	27.1	24.1	3,629.3	NA	32.1
1978	30.2	27.2	4,021.7	2.7	36.6
1979	34.8	31.6	4,556.9	NA	42.3
1980	39.7	34.2	5,217.2	NA	48.8
1981	46.8	36.1	5,950.1	4.4	55.3
1982	58.1	39.7	6,493.1	NA	59.5
1983	66.6	40.7	7,140.3	4.8	63.7
1984	75.4	42.3	7,848.1	NA	70.3
1985	84.8	46.5	8,830.0	5.8	74.3
1986	94.3	50.7	NA	NA	79.4
1987	NA	NA	NA	NA	84.5
Gross national product national currency in billions					
1971	873.1	756.0	82,725.8	57.8	1,102.7
1972	961.3	827.2	96,424.0	63.9	1,212.8
1973	1,121.3	920.1	116,636.3	74.2	1,359.3
1974	1,284.4	986.9	138,044.6	84.3	1,472.8
1975	1,452.0	1,034.9	151,797.0	105.2	1,598.4
1976	1,677.8	1,125.0	170,290.0	125.7	1,782.8
1977	1,885.0	1,200.0	188,804.3	143.2	1,990.5
1978	2,141.0	1,290.7	202,708.0	164.6	2,249.7
1979	2,442.0	1,395.3	218,894.0	191.1	2,508.2
1980	2,765.0	1,484.2	235,834.0	229.5	2,732.0
1981	3,110.6	1,545.1	251,259.0	254.8	3,052.6
1982	3,567.0	1,597.1	263,984.0	278.1	3,166.0
1983	3,935.0	1,674.1	274,639.0	303.2	3,401.6
1984	4,277.2	1,756.9	303,019.8	322.7	3,774.7
1985	4,579.6	1,837.9	320,774.8	337.0	3,996.7
1986	4,857.2	1,949.0	330,712.7	NA	4,291.0
1987	NA	NA	NA	NA	4,491.3

Note: NA = Not available.

Note: The latest data may be preliminary or estimates. The figures for West Germany increased in 1979 in part because of increased coverage of small and medium enterprises not surveyed prior to 1977.

¹ Gross expenditures for performance of R&D including associated capital expenditures, except for the United States, where total capital expenditure data are not available. U.S. estimates for the period 1972-80 show that the inclusion of capital expenditures would have an impact of less than one tenth of one percent of the R&D/GNP ratio.

² Gross domestic product is used for France.

SOURCES: GNP data: International Monetary Fund, *International Financial Statistics*, vol. 30 (May 1977), vol. 31 (May 1978), vol. 31 (August 1978), vol. 32 (January 1979), and vol. 33 (August 1980), U.S. Department of Commerce, *International Economic Indicators* (June 1984); international R&D expenditure data: OECD, *Science and Technology Indicators Recent Results, 1981-87*, September, 1987 and OECD, Science, Technology and Industry Indicators Division, unpublished statistics; United States: Division of Science Resources Studies, National Science Foundation, *National Patterns of Science and Technology Resources*, 1987 (forthcoming)

See figure O-3 in Overview.

Science & Engineering Indicators—1987

Appendix table 4-4. Research and development, by performer: 1960-87

Year	Total	Federal	Industry	U&C	FFRDC's	Nonprofit institutions	Total	Federal	Industry	U&C	FFRDC's	Nonprofit institutions	
	Millions of dollars						Millions constant 1982 dollars ¹						
1960	13,523	1,726	10,509	646	360	282	43,693	5,577	33,955	2,087	1,163	911	
1961	14,316	1,874	10,908	763	410	361	45,826	5,999	34,917	2,442	1,312	1,156	
1962	15,394	2,098	11,464	904	470	458	48,197	6,569	35,892	2,830	1,472	1,434	
1963	17,059	2,279	12,630	1,081	530	539	52,651	7,034	38,981	3,336	1,636	1,664	
1964	18,854	2,838	13,512	1,275	629	600	57,255	8,618	41,032	3,872	1,910	1,822	
1965	20,044	3,093	14,185	1,474	629	663	59,337	9,156	41,992	4,364	1,862	1,963	
1966	21,846	3,220	15,548	1,715	630	733	62,489	9,211	44,474	4,906	1,802	2,097	
1967	23,146	3,396	16,385	1,921	673	771	64,402	9,449	45,590	5,345	1,873	2,145	
1968	24,605	3,494	17,429	2,149	719	814	65,213	9,261	46,194	5,696	1,906	2,157	
1969	25,631	3,503	18,308	2,225	725	870	64,432	8,806	46,023	5,593	1,823	2,187	
1970	26,134	4,079	18,067	2,335	737	916	62,179	9,705	42,986	5,556	1,754	2,179	
1971	26,676	4,228	18,320	2,500	716	912	60,108	9,527	41,280	5,633	1,613	2,055	
1972	28,477	4,590	19,552	2,630	753	952	61,254	9,873	42,056	5,657	1,620	2,048	
1973	30,718	4,762	21,249	2,884	817	1,006	62,006	9,612	42,893	5,822	1,649	2,031	
1974	32,864	4,911	22,887	3,023	865	1,178	60,904	9,101	42,415	5,602	1,603	2,183	
1975	35,213	5,354	24,187	3,409	987	1,276	59,371	9,027	40,781	5,748	1,664	2,151	
1976	39,018	5,769	26,997	3,729	1,147	1,376	61,865	9,147	42,805	5,912	1,819	2,182	
1977	42,783	6,012	29,825	4,067	1,384	1,495	63,589	8,936	44,330	6,045	2,057	2,222	
1978	48,129	6,811	33,304	4,625	1,717	1,672	66,642	9,431	46,115	6,404	2,377	2,315	
1979	54,933	7,417	38,226	5,361	1,935	1,994	69,916	9,440	48,652	6,823	2,463	2,538	
1980	62,593	7,632	44,505	6,060	2,246	2,150	73,020	8,903	51,919	7,070	2,620	2,508	
1981	71,840	8,425	51,810	6,819	2,486	2,300	76,458	8,967	55,140	7,257	2,646	2,448	
1982	79,316	9,141	57,995	7,267	2,479	2,425	79,316	9,141	57,995	7,267	2,479	2,425	
1983	87,204	10,582	63,403	7,807	2,737	2,675	83,963	10,189	61,047	7,517	2,635	2,576	
1984	97,639	11,572	71,471	8,503	3,118	2,975	90,633	10,742	66,343	7,893	2,894	2,762	
1985	107,462	12,998	78,181	9,504	3,529	3,250	96,665	11,692	70,326	8,549	3,174	2,923	
1986	116,793	13,533	85,660	10,600	3,600	3,400	102,405	11,866	75,107	9,294	3,157	2,981	
1987	124,250	15,000	90,700	11,150	3,800	3,600	105,422	12,727	76,956	9,460	3,224	3,054	

¹ GNP implicit price deflator used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources*, 1987 (forthcoming)

Science & Engineering Indicators—1987

Appendix table 4-5. Research and development, by source and performer: 1960-87

	Industry ¹					Universities and colleges ¹					Nonprofit institutions ¹				
Year	Total	Federal ¹	Total	Federal	Industry	Total	Federal	Industry	U&C	NP	FFRDC	Total	Federal	Industry	NP
	Millions of dollars														
1960 ...	13,523	1,726	10,509	6,081	4,428	646	405	40	149	52	360	282	166	48	68
1961 ...	14,316	1,874	10,908	6,240	4,668	763	500	40	165	58	410	361	226	49	86
1962 ...	15,394	2,098	11,464	6,435	5,029	904	613	40	185	66	470	458	295	54	109
1963 ...	17,059	2,279	12,630	7,270	5,360	1,081	760	41	207	73	530	539	365	55	119
1964 ...	18,854	2,838	13,512	7,720	5,792	1,275	917	40	235	83	629	600	433	55	112
1965 ...	20,044	3,093	14,185	7,740	6,445	1,474	1,073	41	267	93	629	663	477	62	124
1966 ...	21,846	3,220	15,548	8,332	7,216	1,715	1,261	42	304	108	630	733	525	70	138
1967 ...	23,146	3,396	16,385	8,365	8,020	1,921	1,409	48	345	119	673	771	552	74	145
1968 ...	24,605	3,494	17,429	8,560	8,869	2,149	1,573	55	390	131	719	814	582	81	151
1969 ...	25,631	3,503	18,308	8,451	9,857	2,225	1,600	60	420	145	725	870	616	93	161
1970 ...	26,134	4,079	18,067	7,779	10,288	2,335	1,648	61	461	165	737	916	649	95	172
1971 ...	26,676	4,228	18,320	7,666	10,654	2,500	1,724	70	529	177	716	912	630	98	184
1972 ...	28,477	4,590	19,552	8,017	11,535	2,630	1,795	74	574	187	753	952	653	101	198
1973 ...	30,718	4,762	21,249	8,145	13,104	2,884	1,985	84	613	202	817	1,006	690	105	211
1974 ...	32,864	4,911	22,887	8,220	14,667	3,023	2,032	96	677	218	865	1,178	822	115	241
1975 ...	35,213	5,354	24,187	8,605	15,582	3,409	2,288	113	749	259	987	1,276	875	125	276
1976 ...	39,018	5,769	26,997	9,561	17,436	3,729	2,512	123	810	284	1,147	1,376	925	135	316
1977 ...	42,783	6,012	29,825	10,485	19,340	4,067	2,726	139	888	314	1,384	1,495	987	150	358
1978 ...	48,129	6,811	33,304	11,189	22,115	4,625	3,059	170	1,037	359	1,717	1,672	1,100	165	407
1979 ...	54,933	7,417	38,226	12,518	25,708	5,361	3,595	193	1,200	373	1,935	1,994	1,350	180	464
1980 ...	62,593	7,632	44,505	14,029	30,476	6,060	4,094	235	1,323	408	2,246	2,150	1,450	200	500
1981 ...	71,840	8,425	51,810	16,382	35,428	6,819	4,562	291	1,520	446	2,486	2,300	1,550	225	525
1982 ...	79,316	9,141	57,995	18,483	39,512	7,267	4,752	334	1,690	500	2,479	2,425	1,650	250	525
1983 ...	87,204	10,582	63,403	20,542	42,861	7,807	4,960	379	1,881	587	2,737	2,675	1,850	275	550
1984 ...	97,639	11,572	71,471	23,163	48,308	8,503	5,388	458	2,024	633	3,118	2,975	2,100	300	575
1985 ...	107,462	12,998	78,181	26,485	51,696	9,504	6,003	538	2,259	704	3,529	3,250	2,315	335	600
1986 ...	116,793	13,533	85,660	30,936	54,724	10,600	6,750	600	2,500	750	3,600	3,400	2,400	375	625
1987 ...	124,250	15,000	90,700	33,000	57,700	11,150	7,000	670	2,700	780	3,800	3,600	2,550	400	650

¹ Performing sector

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources*, 1987 (forthcoming)

Science & Engineering Indicators—1987

Appendix table 4-6. National R&D expenditures, by character of work: 1960-87

Year	Basic research	Applied research	Development	Basic research	Applied research	Development
	Millions of dollars			Millions of constant 1982 dollars ¹		
1960	\$1,197	\$3,020	\$9,306	3,868	9,758	30,068
1961	1,401	3,065	9,850	4,485	9,811	31,530
1962	1,724	3,665	10,005	5,398	11,475	31,324
1963	1,965	3,742	11,352	6,065	11,549	35,037
1964	2,289	4,128	12,437	6,951	12,536	37,768
1965	2,555	4,339	13,150	7,564	12,845	38,928
1966	2,814	4,601	14,431	8,049	13,161	41,279
1967	3,056	4,780	15,310	8,503	13,300	42,599
1968	3,296	5,131	16,178	8,736	13,599	42,878
1969	3,441	5,316	16,874	8,650	13,363	42,418
1970	3,549	5,720	16,865	8,444	13,609	40,126
1971	3,672	5,739	17,265	8,274	12,932	38,903
1972	3,829	5,984	18,664	8,236	12,872	40,146
1973	3,946	6,597	20,175	7,965	13,317	40,725
1974	4,239	7,228	21,397	7,856	13,395	39,653
1975	4,608	7,863	22,742	7,769	13,257	38,344
1976	4,977	9,046	24,995	7,891	14,343	39,631
1977	5,537	9,745	27,501	8,230	14,484	40,875
1978	6,392	10,844	30,893	8,851	15,015	42,776
1979	7,257	12,372	35,304	9,236	15,746	44,933
1980	8,079	14,050	40,464	9,425	16,391	47,205
1981	9,180	16,877	45,783	9,770	17,962	48,726
1982	9,937	18,518	50,861	9,937	18,518	50,861
1983	11,058	20,351	55,795	10,647	19,595	53,721
1984	12,076	21,445	64,118	11,210	19,906	59,517
1985 (Prelim.)	13,222	23,324	70,916	11,893	20,980	63,791
1986(Est.)	14,309	25,020	77,464	12,546	21,938	67,921
1987(Est.)	14,815	26,095	83,340	12,570	22,141	70,711

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

Note: The National Science Foundation uses the following definitions of character of work in its resource surveys.

Basic research - Basic research has as its objective "a fuller knowledge or understanding of the subject under study, rather than a practical application thereof." To take into account industrial goals NSF modifies this definition for the industry sector to indicate that basic research advances scientific knowledge "not having specific commercial objectives, although such investigations may be in fields of present or potential interest to the reporting company."

Applied research - Applied research is directed toward gaining "knowledge or understanding necessary for determining the means by which a recognized and specific need may be met." In industry applied research includes investigations directed "to the discovery of new scientific knowledge having specific commercial objectives with respect to products or processes."

Development - Development is the "systematic use of the knowledge or understanding gained from research, directed toward the production of useful materials, devices systems or methods, including design and development or prototypes and processes."

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming)

See figure O-5 in Overview.

Science & Engineering Indicators—1987

Appendix table 4-7. National research and development expenditures, by sector and character of work: 1985

Sector	Basic research	Applied research	Development
	Millions of dollars		
Universities and colleges ¹	6,377	2,572	555
Non-profit institutions ¹	1,063	869	633
Federally funded research and development centers ²	1,221	1,777	3,063
Federal government	1,961	3,148	7,889
Industry ¹	2,600	14,958	58,776

¹ Excludes federally funded research and development centers.

² Includes university-administered, nonprofit-administered, and industry-administered FFRDCs.

SOURCES: National Science Foundation, *National Patterns of Science and Technology Resources*, 1987 (forthcoming); NSF, *Federal Funds for Research and Development*, Vols. 34 and 35; NSF, *Research and Development in Industry*, 1985

See figure O-23 in Overview.

Science & Engineering Indicators—1987

Appendix table 4-8. Academic research and development and nonacademic basic research: 1960-87

Year	Academic research and development				Nonacademic basic research			
	Millions of		As a percent of		Millions of		As a percent of	
	Current dollars	Constant 1982 dollars ¹	Total R&D	GNP	Current dollars	Constant 1982 dollars ¹	Total R&D	GNP
1960	646	2,077	4.78	0.13	764	2,464	5.65	0.15
1961	763	2,427	5.33	0.14	865	2,762	6.04	0.16
1962	904	2,825	5.87	0.16	1,065	3,332	6.92	0.19
1963	1,081	3,318	6.34	0.18	1,151	3,546	6.75	0.19
1964	1,275	3,858	6.76	0.20	1,286	3,899	6.82	0.20
1965	1,474	4,367	7.35	0.21	1,417	4,196	7.07	0.20
1966	1,715	4,937	7.85	0.22	1,511	4,333	6.92	0.20
1967	1,921	5,347	8.30	0.24	1,599	4,450	6.91	0.20
1968	2,149	5,778	8.73	0.24	1,647	4,392	6.69	0.18
1969	2,225	5,676	8.68	0.23	1,730	4,379	6.75	0.18
1970	2,335	5,629	8.93	0.23	1,753	4,197	6.71	0.17
1971	2,500	5,726	9.37	0.23	1,758	3,993	6.59	0.16
1972	2,630	5,710	9.24	0.22	1,807	3,904	6.35	0.15
1973	2,884	5,965	9.39	0.21	1,893	3,866	6.16	0.14
1974	3,023	5,796	9.20	0.21	2,085	3,926	6.34	0.14
1975	3,409	5,927	9.68	0.21	2,198	3,761	6.24	0.14
1976	3,729	6,007	9.56	0.21	2,428	3,879	6.22	0.14
1977	4,067	6,067	9.51	0.20	2,737	4,076	6.40	0.14
1978	4,625	6,449	9.61	0.21	3,216	4,469	6.68	0.14
1979	5,361	6,882	9.76	0.21	3,645	4,659	6.64	0.15
1980	6,060	7,151	9.68	0.22	4,053	4,755	6.48	0.15
1981	6,819	7,316	9.49	0.22	4,604	4,919	6.41	0.15
1982	7,276	7,276	9.17	0.23	5,080	5,080	6.40	0.16
1983	7,807	7,490	8.95	0.23	5,789	5,565	6.64	0.17
1984	8,503	7,859	8.71	0.23	6,438	5,965	6.59	0.17
1985	9,504	8,509	8.84	0.24	6,845	6,144	6.37	0.17
1986 (Est.)	10,600	9,229	9.08	0.25	7,209	6,302	6.17	0.17
1987 (Est.)	11,150	9,439	8.97	0.25	7,445	6,311	5.99	0.17

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources*: 1987 (forthcoming), and unpublished data

See figure 4-1.

Science & Engineering Indicators—1987

Appendix table 4-9. Nonacademic applied research: 1960-87

Year	Nonacademic ¹ applied research		Research and development		Nonacademic applied research as a percent of R&D
	Current dollars	Constant ² dollars	Current dollars	Constant ² dollars	Percent
Millions of dollars					
1960	\$2,841	\$9,168	\$13,523	\$43,648	21.0
1961	2,873	9,181	14,316	45,764	20.1
1962	3,460	10,827	15,394	48,176	22.5
1963	3,515	10,833	17,059	52,585	20.6
1964	3,896	11,819	18,854	57,202	20.7
1965	4,060	12,022	20,044	59,351	20.3
1966	4,273	12,245	21,846	62,589	19.6
1967	4,406	12,260	23,146	64,406	19.0
1968	4,727	12,580	24,605	65,458	19.2
1969	4,909	12,390	25,631	64,672	19.2
1970	5,293	12,642	26,134	62,405	20.3
1971	5,265	11,919	26,676	60,385	19.7
1972	5,460	11,776	28,477	61,414	19.2
1973	5,884	11,962	30,718	62,427	19.2
1974	6,492	12,146	32,864	61,467	19.8
1975	7,012	11,928	35,213	59,883	19.9
1976	8,030	12,793	39,018	62,134	20.6
1977	8,678	12,912	42,783	63,653	20.3
1978	9,631	13,362	48,129	66,769	20.0
1979	10,907	13,914	54,933	70,077	19.9
1980	12,359	14,460	62,593	73,235	19.7
1981	15,011	16,006	71,840	76,610	20.9
1982	16,514	16,514	79,316	79,316	20.8
1983	18,250	17,558	87,204	83,891	20.9
1984	19,055	17,673	97,639	90,542	19.5
1985	20,752	18,649	107,462	96,556	19.3
1986 (Est.)	22,120	19,370	116,793	102,236	18.9
1987 (Est.)	23,015	19,519	124,250	105,364	18.5

¹ National expenditures for applied research minus applied research funds spent at universities and colleges.

² GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources: 1987* (forthcoming)

Science & Engineering Indicators—1987

Appendix table 4-10. Sources of support for academic research and development: 1960-87

Fiscal year	Total	Federal government	State & local governments	Industry	Institutional funds	All other sources
Millions of dollars						
1960	646	405	85	40	64	52
1961	763	500	95	40	70	58
1962	904	613	106	40	79	66
1963	1,081	760	118	41	89	73
1964	1,275	917	132	40	103	83
1965	1,474	1,073	143	41	124	93
1966	1,715	1,261	156	42	148	108
1967	1,921	1,409	164	48	181	119
1968	2,149	1,572	172	55	218	132
1969	2,225	1,600	197	60	223	145
1970	2,335	1,647	219	61	243	165
1971	2,500	1,724	255	70	274	177
1972	2,630	1,795	269	74	305	187
1973	2,884	1,985	295	84	318	202
1974	3,022	2,032	308	95	368	219
1975	3,409	2,288	332	113	417	259
1976	3,729	2,512	364	123	446	285
1977	4,067	2,726	374	139	514	314
1978 ¹	4,625	3,059	414	170	623	359
1979	5,361	3,595	470	194	728	374
1980	6,061	4,097	491	237	827	408
1981	6,810	4,557	544	291	972	445
1982	7,266	4,747	609	333	1,078	499
1983	7,798	4,953	624	378	1,256	587
1984	8,508	5,386	683	461	1,350	629
1985	9,524	5,998	729	543	1,557	698
1986	10,718	6,633	903	667	1,774	740
1987 (est.)	11,150	7,000	NA	670	NA	NA
Millions constant 1982 dollars ²						
1960	2,087	1,309	275	129	207	168
1961	2,442	1,601	304	128	224	186
1962	2,830	1,919	332	125	247	207
1963	3,336	2,346	364	127	275	225
1964	3,872	2,785	401	121	313	252
1965	4,364	3,176	423	121	367	275
1966	4,906	3,607	446	120	423	309
1967	5,345	3,920	456	134	504	331
1968	5,696	4,166	456	146	578	350
1969	5,593	4,022	495	151	561	365
1970	5,556	3,919	521	145	578	393
1971	5,633	3,885	575	158	617	399
1972	5,657	3,861	579	159	656	402
1973	5,822	4,007	595	170	642	408
1974	5,600	3,766	571	176	682	406
1975	5,748	3,858	560	191	703	437
1976	5,912	3,983	577	195	707	452
1977	6,045	4,052	556	207	764	467
1978 ¹	6,404	4,236	573	235	863	497
1979	6,823	4,576	598	247	927	476
1980	7,071	4,780	573	276	965	476
1981	7,248	4,850	579	310	1,034	474
1982	7,266	4,747	609	333	1,078	499
1983	7,508	4,769	601	364	1,209	565
1984	7,898	5,000	634	428	1,253	584
1985	8,567	5,395	656	488	1,401	628
1986	9,398	5,816	792	585	1,555	649
1987 (est.)	9,460	5,939	NA	568	NA	NA

(continued)

Appendix table 4-10. (Continued)

As a percent of total academic R&D						
Year	100.0	62.7	13.2	6.2	9.9	8.0
1960	100.0	62.7	13.2	6.2	9.9	8.0
1961	100.0	65.5	12.5	5.2	9.2	7.6
1962	100.0	67.8	11.7	4.4	8.7	7.3
1963	100.0	70.3	10.9	3.8	8.2	6.8
1964	100.0	71.9	10.4	3.1	8.1	6.5
1965	100.0	72.8	9.7	2.8	8.4	6.3
1966	100.0	73.5	9.1	2.4	8.6	6.3
1967	100.0	73.3	8.5	2.5	9.4	6.2
1968	100.0	73.2	8.0	2.6	10.1	6.1
1969	100.0	71.9	8.9	2.7	10.0	6.5
1970	100.0	70.5	9.4	2.6	10.4	7.1
1971	100.0	69.0	10.2	2.8	11.0	7.1
1972	100.0	68.3	10.2	2.8	11.6	7.1
1973	100.0	68.8	10.2	2.9	11.0	7.0
1974	100.0	67.2	10.2	3.1	12.2	7.2
1975	100.0	67.1	9.7	3.3	12.2	7.6
1976	100.0	67.4	9.8	3.3	12.0	7.6
1977	100.0	67.0	9.2	3.4	12.6	7.7
1978 ¹	100.0	66.1	9.0	3.7	13.5	7.8
1979	100.0	67.1	8.8	3.6	13.6	7.0
1980	100.0	67.6	8.1	3.9	13.6	6.7
1981	100.0	66.9	8.0	4.3	14.3	6.5
1982	100.0	65.3	8.4	4.6	14.8	6.9
1983	100.0	63.5	8.0	4.8	16.1	7.5
1984	100.0	63.3	8.0	5.4	15.9	7.4
1985	100.0	63.0	7.7	5.7	16.3	7.3
1986	100.0	61.9	8.4	6.2	16.6	6.9
1987 (est.)	100.0	62.8	NA	6.0	NA	NA

¹ Estimated, based on data collected from doctorate-granting institutions only.

² GNP deflator used to convert current to constant dollars.

SOURCE: National Science Foundation, *Academic Science and Engineering, R&D Funds, FY 1986*, and unpublished data.

See figure O-31 in Overview.

Science & Engineering Indicators—1987

Appendix table 4-11. Federal obligations for academic research and development, by agency: 1967-87

Year	All agencies	Total agencies	DOE ¹	DOD	NIH	NASA	NSF	USDA	Other agencies
— Millions of dollars —									
1967	\$1,454	\$1,240	\$90	\$280	\$478	\$119	\$209	\$64	\$214
1968	1,487	1,252	93	244	525	108	221	61	235
1969	1,529	1,273	101	263	535	99	213	62	256
1970	1,476	1,238	100	216	518	111	228	65	238
1971	1,645	1,366	94	211	603	119	267	72	279
1972	1,904	1,641	85	217	756	134	362	87	263
1973	1,917	1,647	83	204	761	131	374	94	270
1974	2,214	1,927	94	197	1,027	125	389	95	287
1975	2,411	2,086	132	203	1,077	131	435	108	325
1976	2,552	2,251	145	240	1,185	124	437	120	301
1977	2,905	2,541	188	273	1,311	118	511	140	364
1978	3,375	2,966	240	383	1,493	127	537	186	409
1979	3,889	3,419	260	438	1,765	139	617	200	470
1980	4,263	3,727	285	495	1,888	158	685	216	536
1981	4,466	3,973	300	573	1,984	171	702	243	493
1982	4,605	4,123	277	664	2,026	186	715	255	482
1983	4,966	4,532	297	724	2,264	189	783	275	434
1984	5,565	5,074	321	830	2,560	222	880	261	491
1985	6,299	5,765	357	940	2,918	255	1,002	293	534
1986 (Est.)	6,555	6,001	328	1,074	3,033	305	994	267	554
1987 (Est.)	6,559	6,097	315	1,232	2,846	325	1,143	236	462
— Millions constant 1982 dollars ² —									
1967	4,048	3,451	250	779	1,330	331	582	178	596
1968	3,998	3,366	250	656	1,412	290	594	164	632
1969	3,901	3,247	258	671	1,365	253	543	158	653
1970	3,558	2,985	241	521	1,249	268	550	157	574
1971	3,768	3,129	215	483	1,381	273	612	165	639
1972	4,134	3,563	185	471	1,641	291	786	189	571
1973	3,965	3,406	172	422	1,574	271	774	194	558
1974	4,245	3,694	180	378	1,969	240	746	182	550
1975	4,192	3,627	229	353	1,872	228	756	188	565
1976	4,111	3,626	234	387	1,909	200	704	193	485
1977	4,334	3,791	280	407	1,956	176	762	209	543
1978	4,706	4,136	335	534	2,082	177	749	259	570
1979	4,992	4,389	334	562	2,266	178	792	257	603
1980	5,031	4,398	336	584	2,228	186	808	255	633
1981	4,791	4,262	322	615	2,129	183	753	261	529
1982	4,605	4,123	277	664	2,026	186	715	255	482
1983	4,764	4,348	285	695	2,172	181	751	264	416
1984	5,144	4,690	297	767	2,366	205	813	241	454
1985	5,640	5,162	320	842	2,613	228	897	262	478
1986 (Est.)	5,707	5,225	286	935	2,641	266	865	232	482
1987 (Est.)	5,552	5,161	267	1,043	2,409	275	968	200	391

¹ Atomic Energy Commission, 1967-73; Energy Research and Development Administration, 1974-76; Department of Energy 1977-87.

² GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables, FY 1955-87*

Science & Engineering Indicators—1987

Appendix table 4-12. Forms of Federal support for academic science and engineering, and NIH indirect cost ratio: 1966-86

	Research & development plant	Fellowships, traineeships & training grants	General support for s/e	Other s/e activities	Research & development	NIH Indirect cost ratio ¹
	Thousands of dollars					(Percent)
1966	114,767	365,560	(²)	431,031	1,252,146	15.3
1967	111,309	447,236	(²)	464,008	1,301,242	16.9
1968	96,148	440,895	(²)	414,469	1,398,305	19.1
1969	54,516	436,270	(²)	395,932	1,474,681	20.9
1970	44,778	429,408	(²)	266,775	1,446,618	22.2
1971	29,942	421,029	99,669	212,369	1,551,391	22.6
1972	36,917	387,888	83,288	211,592	1,852,963	20.6
1973	43,338	287,210	38,964	210,788	1,870,690	23.2
1974	29,009	326,600	86,974	205,691	2,085,204	24.4
1975	44,787	201,273	46,353	262,256	2,246,088	25.9
1976	23,899	174,871	74,483	252,223	2,430,970	26.7
1977	36,471	184,671	75,928	247,968	2,803,017	27.2
1978	34,328	205,925	74,398	254,505	3,385,770	27.2
1979	32,068	204,866	92,483	262,985	3,873,514	27.8
1980	37,780	210,121	91,541	287,211	4,159,857	28.6
1981	27,694	205,448	92,721	321,499	4,410,199	29.5
1982	31,200	176,582	80,137	336,387	4,553,755	30.0
1983	37,547	189,616	94,847	331,769	5,023,677	30.5
1984	49,764	194,895	112,588	396,432	5,634,400	31.2 ³
1985	113,932	253,082	119,171	389,746	6,368,608	31.7 ³
1986	105,827	246,196	111,130	392,698	6,538,280	NA

¹ The indirect cost rate is the percent of total grant support which goes to indirect costs of research. The NIH ratio is used here as a proxy for all Federal research. Other estimates are lower. See, for example, General Accounting Office, "University Finances: Research Revenues and Expenditures," GAO RCED-86-162BR, July 1986, which estimates the all-agency indirect cost rate in 1984 at 25 percent (p. 30).

² Not separately classified, included under other science/engineering activities.

³ Projected.

SOURCES: National Science Foundation, *Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, FY 1985*, National Institutes of Health Federal Assistance Accounting Branch

See figure 4-2.

Science & Engineering Indicators—1987

**Appendix table 4-13. Sources of support for nonacademic¹ basic research:
1960-87**

Year	Total	Federal Government	Industry	Other Nonprofit institutions
—Millions of dollars—				
1960	\$ 764	\$ 416	\$ 318	\$30
1961	865	492	336	37
1962	1,065	650	369	46
1963	1,151	701	400	50
1964	1,286	830	409	47
1965	1,417	930	435	52
1966	1,511	970	483	58
1967	1,599	1,077	461	61
1968	1,647	1,085	499	63
1969	1,730	1,162	501	67
1970	1,753	1,193	488	72
1971	1,758	1,180	501	77
1972	1,807	1,213	510	84
1973	1,893	1,255	548	90
1974	2,085	1,389	590	106
1975	2,198	1,445	633	120
1976	2,428	1,595	698	135
1977	2,737	1,816	771	150
1978	3,216	2,181	865	170
1979	3,645	2,472	978	195
1980	4,053	2,708	1,130	215
1981	4,604	2,961	1,418	225
1982	5,090	3,250	1,615	215
1983	5,789	3,737	1,832	220
1984	6,438	4,110	2,103	225
1985	6,845	4,359	2,256	230
1986 (Est.)	7,209	4,570	2,399	240
1987 (Est.)	7,445	4,665	2,530	250
—Millions constant 1982 dollars ² —				
1960	\$2,468	\$1,344	\$1,027	\$97
1961	2,769	1,575	1,076	118
1962	3,334	2,035	1,155	144
1963	3,552	2,164	1,235	154
1964	3,905	2,520	1,242	143
1965	4,195	2,753	1,288	154
1966	4,322	2,775	1,382	166
1967	4,449	2,997	1,283	170
1968	4,365	2,876	1,323	167
1969	4,349	2,921	1,259	168
1970	4,171	2,838	1,161	171
1971	3,961	2,659	1,129	174
1972	3,887	2,609	1,097	181
1973	3,821	2,533	1,106	182
1974	3,864	2,574	1,093	196
1975	3,706	2,436	1,067	202
1976	3,850	2,529	1,107	214
1977	4,068	2,699	1,146	223
1978	4,453	3,020	1,198	235
1979	4,639	3,146	1,245	248
1980	4,728	3,159	1,318	251
1981	4,900	3,151	1,509	239
1982	5,090	3,250	1,615	215
1983	5,574	3,598	1,764	212
1984	5,976	3,815	1,952	209
1985	6,157	3,921	2,029	207
1986 (Est.)	6,321	4,007	2,103	210
1987 (Est.)	6,317	3,958	2,147	212

¹ Expenditures for basic research minus basic research funds sent to universities and colleges.

² GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources*, 1987 (forthcoming)

Science & Engineering Indicators—1987

Appendix table 4-14. Federal obligations for basic research at FFRDC's, by agency: 1967-88

Year	All agencies	DOE ¹	DOD	NIH	NASA	NSF	All other agencies
Millions of dollars							
1967	\$242	\$207	\$2	\$0	\$14	\$17	\$2
1968	258	202	4	0	28	21	2
1969	253	199	4	0	21	25	3
1970	270	203	2	0	39	24	2
1971	259	200	0	0	27	30	1
1972	294	201	1	1	49	42	0
1973	272	213	1	1	23	34	0
1974	261	209	5	2	4	40	1
1975	319	255	2	10	12	40	1
1976	353	276	1	19	9	45	1
1977	383	316	1	8	10	46	0
1978	428	345	2	16	9	55	0
1979	467	358	10	18	12	69	0
1980	515	395	25	18	16	61	0
1981	572	437	31	19	12	73	0
1982	613	491	6	23	19	74	0
1983	682	558	11	19	18	76	0
1984	752	607	14	20	19	91	0
1985	823	672	13	21	24	87	6
1986	822	675	11	26	22	83	4
1987 (Est.)	912	744	15	32	24	92	4
1988 (Est.)	987	814	7	28	35	99	4
As a percent of all agencies							
1967	100.0	85.6	0.9	0.0	5.7	7.0	0.9
1968	100.0	78.3	1.5	0.1	10.8	8.3	0.9
1969	100.0	78.8	1.8	0.0	8.5	9.7	1.2
1970	100.0	75.2	0.7	0.1	14.5	8.9	0.6
1971	100.0	77.3	0.2	0.2	10.6	11.6	0.2
1972	100.0	68.2	0.2	0.3	16.8	14.5	0.0
1973	100.0	78.4	0.5	0.3	8.3	12.5	0.0
1974	100.0	80.2	1.9	0.7	1.4	15.3	0.4
1975	100.0	79.8	0.5	3.1	3.8	12.4	0.3
1976	100.0	78.3	0.4	5.5	2.7	12.7	0.4
1977	100.0	82.7	0.3	2.2	2.6	12.1	0.1
1978	100.0	80.6	0.4	3.7	2.2	13.0	0.1
1979	100.0	76.6	2.1	3.9	2.6	14.8	0.0
1980	100.0	76.8	4.9	3.4	3.1	11.8	0.0
1981	100.0	76.4	5.5	3.2	2.2	12.7	0.0
1982	100.0	80.1	0.9	3.7	3.1	12.1	0.0
1983	100.0	81.9	1.6	2.7	2.6	11.1	0.1
1984	100.0	80.7	1.8	2.7	2.6	12.2	0.0
1985	100.0	81.6	1.6	2.6	2.9	10.5	0.7
1986	100.0	82.2	1.3	3.2	2.7	10.1	0.5
1987 (Est.)	100.0	81.6	1.7	3.5	2.7	10.1	0.5
1988 (Est.)	100.0	82.5	0.7	2.8	3.6	10.0	0.4

¹ Atomic Energy Commission, 1967-1973; Energy Research and Development Administration, 1974-1976; Department of Energy, 1977-present.

SOURCES: National Science Foundation, *Federal Funds for Research and Development: FY 1986, 1987, and 1988*, Vol. XXXVI; National Science Foundation, *Federal Funds for Research and Development: Detailed Historical Tables: FY 1955-1987*

Science & Engineering Indicators—1987

Appendix table 4-15. Federal obligations for basic research to intramural performers, by agency: 1967-87

Year	All agencies	DOE ¹	DOD	NIH	NASA	NSF	USDA	All other agencies
Millions of dollars								
1967	\$435	\$5	\$82	\$65	\$110	\$11	\$63	\$99
1968	432	2	86	75	88	11	67	103
1969	532	2	90	85	153	14	77	111
1970	558	1	148	88	134	11	85	91
1971	565	1	141	107	128	14	87	87
1972	597	1	153	120	133	14	97	79
1973	608	1	144	125	141	8	100	89
1974	696	2	145	149	164	46	103	87
1975	734	0	143	164	173	38	107	109
1976	786	0	162	187	147	58	120	112
1977	914	1	166	204	192	75	144	132
1978	1,029	7	164	245	221	77	161	154
1979	1,089	5	183	281	221	57	169	173
1980	1,182	6	199	320	225	68	180	184
1981	1,302	6	226	335	216	99	202	218
1982	1,466	7	246	405	251	112	219	226
1983	1,690	18	276	449	305	126	239	277
1984	1,861	11	303	479	345	130	274	319
1985	1,961	21	301	543	318	138	296	344
1986	2,018	25	308	579	363	126	293	323
1987 (Est) ...	2,218	34	271	700	418	131	313	351
1988 (Est.) ..	2,176	24	290	608	418	157	330	349
As a percent of all agencies								
1967	100.0	1.1	18.9	14.9	25.3	2.5	14.5	22.8
1968	100.0	0.5	19.9	17.4	20.4	2.5	15.5	23.8
1969	100.0	0.4	16.9	16.0	28.8	2.6	14.5	20.9
1970	100.0	0.2	26.5	15.8	24.0	2.0	15.2	16.3
1971	100.0	0.2	25.0	18.9	22.7	2.5	15.4	15.4
1972	100.0	0.2	25.6	20.1	22.3	2.3	16.2	13.2
1973	100.0	0.2	23.7	20.6	23.2	1.3	16.4	14.6
1974	100.0	0.3	20.8	21.4	23.6	6.6	14.8	12.5
1975	100.0	0.0	19.5	22.3	23.6	5.2	14.6	14.9
1976	100.0	0.0	20.6	23.8	18.7	7.4	15.3	14.2
1977	100.0	0.1	18.2	22.3	21.0	8.2	15.8	14.4
1978	100.0	0.7	15.9	23.8	21.5	7.5	15.6	15.0
1979	100.0	0.5	16.8	25.8	20.3	5.2	15.5	15.9
1980	100.0	0.5	16.8	27.1	19.0	5.8	15.2	15.6
1981	100.0	0.5	17.4	25.7	16.6	7.6	15.5	16.7
1982	100.0	0.5	16.8	27.6	17.1	7.6	14.9	15.4
1983	100.0	1.1	16.3	26.6	18.0	7.5	14.1	16.4
1984	100.0	0.6	16.3	25.7	18.5	7.0	14.7	17.1
1985	100.0	1.1	15.3	27.7	16.2	7.0	15.1	17.5
1986	100.0	1.2	15.3	28.7	18.0	6.2	14.5	16.0
1987 (Est) ...	100.0	1.5	12.2	31.6	18.8	5.9	14.1	15.8
1988 (Est.) ..	100.0	1.1	13.3	27.9	19.2	7.2	15.2	16.0

¹ Atomic Energy Commission, 1967-1973; Energy Research and Development Administration, 1974-1976; Department of Energy, 1977-present.

SOURCES: National Science Foundation, *Federal Funds for Research and Development: FY 1986, 1987, and 1988*, Vol. XXXVI; National Science Foundation, *Federal Funds for Research and Development: Detailed Historical Tables: FY 1955-1987*

Science & Engineering Indicators—1987

Appendix table 4-16. Expenditures for basic research in industry, by source of funds: 1960-87

Year	Current dollars			Constant 1982 dollars ¹			Percent	
	Total	Federal	Nonfederal	Total	Federal	Nonfederal	Federal	Nonfederal
Millions of dollars								
1960	\$ 376	\$79	\$ 297	\$1,215	\$255	\$ 960	21.0%	79.0%
1961	395	81	314	1,264	259	1,005	20.5	79.5
1962	488	143	345	1,528	448	1,080	29.3	70.7
1963	522	147	375	1,611	454	1,157	28.2	71.8
1964	549	165	384	1,667	501	1,166	30.1	69.9
1965	592	186	406	1,753	551	1,202	31.4	68.6
1966	624	173	451	1,785	495	1,290	27.7	72.3
1967	629	202	427	1,750	562	1,188	32.1	67.9
1968	642	180	462	1,702	477	1,224	28.0	72.0
1969	618	160	458	1,554	402	1,151	25.9	74.1
1970	602	158	444	1,432	376	1,056	26.2	73.8
1971	590	134	456	1,329	302	1,027	22.7	77.3
1972	593	130	463	1,276	280	996	21.9	78.1
1973	631	132	499	1,274	266	1,007	20.9	79.1
1974	699	163	536	1,295	302	993	23.3	76.7
1975	730	157	573	1,231	265	966	21.5	78.5
1976	819	185	634	1,299	293	1,005	22.6	77.4
1977	911	210	701	1,354	312	1,042	23.1	76.9
1978	1,035	250	785	1,433	346	1,087	24.2	75.8
1979	1,158	265	893	1,474	337	1,137	22.9	77.1
1980	1,325	290	1,035	1,546	338	1,207	21.9	78.1
1981	1,614	301	1,313	1,718	320	1,397	18.6	81.4
1982	1,880	380	1,500	1,880	380	1,500	20.2	79.8
1983	2,152	460	1,692	2,072	443	1,629	21.4	78.6
1984	2,475	471	2,004	2,297	437	1,860	19.0	81.0
1985	2,628	476	2,152	2,364	428	1,936	18.1	81.9
1986 (Est.)	2,794	524	2,270	2,450	459	1,990	18.8	81.2
1987 (Est.)	3,000	600	2,400	2,545	509	2,036	20.0	80.0

Note: Data include federally funded R&D centers administered by industry. Detail may not add to totals because of rounding.

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCES: 1960-64: National Science Foundation, *National Patterns of Science and Technology Resources, 1981* (NSF 81-311), p.21; 1965-84: National Science Foundation, *National Patterns of Science and Technology Resources, 1984* (NSF 84-311), p.28; 1985-87: National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming)

Science & Engineering Indicators—1987

Appendix table 4-17. Federal obligations for basic research in industry, by agency: 1967-88

Year	All agencies	DOE ¹	DOD	NIH	NASA	NSF	All other agencies
Millions of dollars							
1967	\$181	\$2	\$28	\$10	\$138	\$2	\$2
1968	195	2	21	8	163	1	1
1969	185	2	18	5	154	2	5
1970	185	1	30	6	146	1	1
1971	167	1	42	7	114	1	1
1972	151	1	37	10	97	2	4
1973	176	0	35	11	125	3	2
1974	124	1	38	16	64	3	3
1975	119	0	42	11	53	6	6
1976	131	0	41	14	66	6	3
1977	208	1	51	13	135	5	4
1978	248	2	57	14	153	12	9
1979	277	2	66	19	175	6	9
1980	325	4	88	18	195	11	10
1981	293	7	77	18	161	20	11
1982	271	6	100	13	119	20	12
1983	306	25	105	20	127	21	7
1984	394	22	91	28	215	24	14
1985	404	23	92	27	210	32	20
1986	545	19	94	34	314	58	27
1987 (Est.)	647	36	91	41	383	61	35
1988 (Est.)	571	27	99	35	300	73	36
As a percent of all agencies							
1967	100.0	1.0	15.6	5.3	76.3	0.8	0.9
1968	100.0	0.9	10.7	3.9	83.4	0.6	0.5
1969	100.0	0.9	9.5	2.8	83.4	0.8	2.5
1970	100.0	0.6	16.0	3.3	79.0	0.5	0.6
1971	100.0	0.6	25.4	4.0	68.6	0.7	0.6
1972	100.0	0.4	24.4	6.8	64.3	1.2	3.0
1973	100.0	0.1	20.1	6.2	71.2	1.4	1.1
1974	100.0	0.5	30.4	12.6	51.7	2.3	2.4
1975	100.0	0.1	35.3	9.6	45.0	5.5	4.7
1976	100.0	0.2	31.4	10.8	50.2	4.8	2.6
1977	100.0	0.3	24.5	6.1	64.7	2.4	2.0
1978	100.0	0.7	23.2	5.7	61.8	4.9	3.7
1979	100.0	0.7	23.8	7.0	63.0	2.3	3.3
1980	100.0	1.3	26.9	5.4	59.8	3.4	3.1
1981	100.0	2.5	26.1	6.2	54.9	6.7	3.6
1982	100.0	2.4	37.0	4.9	43.9	7.4	4.4
1983	100.0	8.3	34.2	6.6	41.7	6.9	2.4
1984	100.0	5.5	23.0	7.1	54.4	6.2	3.7
1985	100.0	5.7	22.9	6.6	51.9	8.0	4.9
1986	100.0	3.5	17.2	6.2	57.6	10.7	4.9
1987 (Est.)	100.0	5.6	14.1	6.3	59.2	9.4	5.4
1988 (Est.)	100.0	4.8	17.4	6.2	52.5	12.8	6.3

¹ Atomic Energy Commission, 1967-1973; Energy Research and Development Administration, 1974-1976; Department of Energy, 1977-present.

SOURCE: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables: FY 1955-1987*; National Science Foundation, *Federal Funds for Research and Development, FY 1986, 1987, and 1988*, vol. XXXVI

Science & Engineering Indicators—1987

Appendix table 4-18. Federal obligations for basic research, by field: 1976-88

Field	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987 (Est.)	1988 (Est.)
Thousands of dollars													
Total	2,767,454	3,258,640	3,698,604	4,192,665	4,674,156	5,041,295	5,481,605	6,260,131	7,067,359	7,818,682	8,153,076	8,821,058	9,134,000
Total sciences	2,494,655	2,920,957	3,306,043	3,758,007	4,208,928	4,515,277	4,871,138	5,570,628	6,222,368	6,931,850	7,184,568	7,799,038	8,079,000
Physical sciences	721,435	889,994	941,421	1,050,002	1,220,588	1,324,940	1,393,844	1,587,183	1,727,982	1,813,988	1,914,426	2,122,818	2,187,500
Chemistry	168,265	208,695	203,260	224,798	256,922	298,188	312,002	362,188	403,367	420,847	433,359	464,253	475,300
Physics	388,440	467,414	518,798	535,624	668,155	735,417	790,741	855,104	921,430	962,805	1,003,363	1,104,210	1,175,200
Math & Computer sciences	81,805	83,408	97,737	104,164	116,258	140,360	165,064	208,129	240,806	260,633	293,389	299,972	332,500
Environmental sciences	294,325	387,454	451,278	457,284	522,360	532,833	520,049	580,050	656,731	699,675	749,093	794,858	878,300
Atmospheric sciences	114,007	143,464	163,275	169,172	179,048	173,829	163,195	172,633	192,172	209,215	240,417	257,951	275,000
Geological sciences	95,705	128,720	145,114	157,603	198,335	194,205	177,487	178,292	198,010	249,988	265,478	267,905	300,100
Oceanography	76,580	104,593	120,720	119,110	130,678	143,294	154,465	195,615	220,131	219,258	224,304	249,040	283,700
Life sciences	1,222,015	1,383,365	1,588,390	1,891,777	2,054,425	2,223,848	2,526,017	2,891,336	3,287,634	3,807,527	3,858,783	4,168,840	4,270,900
Psychology	45,529	55,717	67,473	75,069	84,206	90,992	89,875	92,927	107,861	130,092	132,955	150,287	146,700
Social sciences	86,426	95,513	124,347	129,718	147,180	136,951	120,198	137,723	132,581	141,208	113,464	131,480	133,100
Other sciences	43,120	25,506	35,397	49,993	63,911	65,353	56,091	73,280	68,773	78,727	122,458	130,783	129,900
Total engineering	272,799	337,683	392,561	434,658	465,228	526,018	610,467	689,503	844,991	886,832	968,508	1,022,020	1,054,600
Thousands of constant 1982 dollars ¹													
Total	4,457,883	4,861,465	5,157,005	5,382,112	5,515,879	5,408,534	5,481,605	6,006,074	6,532,359	7,000,342	7,098,891	7,467,246	7,423,000
Total sciences	4,018,452	4,357,686	4,609,653	4,824,142	4,966,873	4,844,198	4,871,138	5,344,553	5,751,334	6,206,330	6,255,610	6,602,081	6,565,900
Physical sciences	1,162,105	1,327,755	1,312,634	1,347,884	1,440,392	1,421,457	1,393,844	1,522,770	1,597,173	1,624,127	1,666,892	1,797,019	1,777,700
Chemistry	271,045	311,346	283,408	288,573	303,189	319,910	312,002	347,489	372,832	376,799	377,326	393,002	386,300
Physics	625,709	697,321	723,366	687,579	788,477	788,989	790,741	820,401	851,678	862,033	873,629	934,741	955,000
Math & Computer sciences	131,774	124,434	136,276	133,715	137,194	150,585	165,064	199,682	222,577	233,354	255,454	253,934	270,200
Environmental sciences	474,106	578,031	629,222	587,014	616,427	571,648	520,049	556,510	607,016	626,444	652,236	672,867	713,800
Atmospheric sciences	183,645	214,030	227,656	217,166	211,291	186,492	163,195	165,627	177,625	187,318	209,331	218,362	223,400
Geological sciences	154,164	192,033	202,334	202,315	234,051	208,352	177,487	171,056	183,021	223,823	231,152	226,788	243,900
Oceanography	123,357	156,039	168,321	152,901	154,211	153,732	154,465	187,676	203,467	196,309	195,302	210,819	230,600
Life sciences	1,968,452	2,063,800	2,214,710	2,428,469	2,424,386	2,385,847	2,526,017	2,773,996	3,038,760	3,409,013	3,359,846	3,529,027	3,470,900
Psychology	73,339	83,122	94,078	96,366	99,370	97,620	89,875	89,156	99,696	116,476	115,764	127,222	119,200
Social sciences	139,217	142,493	173,378	166,519	173,684	146,927	120,198	132,134	122,545	126,429	98,793	111,301	108,200
Other sciences	69,459	38,052	49,354	64,176	75,420	70,114	56,091	70,306	63,567	70,487	106,624	110,711	105,600
Total engineering	439,431	503,779	547,352	557,969	549,006	564,336	610,467	661,521	781,025	794,012	843,281	865,165	857,100

¹ GNP implicit price deflator used to convert current to constant dollars.

SOURCE: National Science Foundation, *Federal Funds for Research and Development, Detailed Historical Tables, FY 1955-87*; National Science Foundation, *Federal Funds for Research and Development, FY 1986, 1987, and 1988*, vol. XXXVI.

Appendix table 4-19. Expenditures for research and development by universities and colleges, by field: 1976-86

Fields	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Thousands of dollars											
Total	\$3,729,007	\$4,066,953	\$4,624,673	\$5,361,408	\$6,060,629	\$6,809,552	\$7,266,122	\$7,798,179	\$8,508,380	\$9,527,293	\$10,718,402
Total sciences	3,297,280	3,568,480	4,023,611	4,593,001	5,195,705	5,848,875	6,240,609	6,687,368	7,301,276	8,137,576	9,109,309
Physical sciences	379,379	423,457	496,399	601,904	677,293	764,673	822,584	897,099	991,917	1,133,913	1,261,376
Astronomy	26,294	32,361	36,782	48,459	58,740	67,337	73,237	74,177	80,457	91,049	96,335
Chemistry	140,142	159,353	183,131	206,421	243,982	283,899	308,091	334,663	367,843	411,615	460,084
Physics	183,050	201,655	235,099	292,033	322,230	356,859	365,897	414,165	469,403	550,045	622,296
Other physical sciences	29,893	30,088	41,387	54,991	52,341	56,578	75,359	74,094	74,215	81,204	82,661
Environmental sciences	288,531	319,398	379,391	452,915	509,038	548,920	557,817	618,962	649,601	705,357	774,177
Atmospheric	NA	NA	NA	NA	67,459	78,257	85,443	97,660	102,875	109,549	124,826
Earth sciences	NA	NA	NA	NA	188,226	189,692	195,507	216,159	225,525	250,534	261,849
Oceanography	NA	NA	NA	NA	171,668	187,463	197,701	223,994	238,157	260,306	275,524
Other environmental sciences	NA	NA	NA	NA	81,685	93,506	79,166	81,149	83,044	84,966	111,978
Mathematical sciences	42,491	52,312	58,756	78,477	78,667	88,793	98,568	108,038	124,398	129,799	152,204
Computer sciences	44,503	55,563	67,422	97,921	114,196	132,884	149,259	175,236	222,480	279,181	315,360
Life sciences	2,101,695	2,258,806	2,538,004	2,832,523	3,217,658	3,670,596	3,969,593	4,233,143	4,617,226	5,155,422	5,746,125
Agricultural sciences	412,867	460,647	521,745	602,485	679,880	772,434	844,040	895,520	930,245	1,028,549	1,122,363
Biological sciences	710,724	772,290	808,500	914,806	1,030,429	1,186,333	1,286,548	1,408,240	1,555,330	1,697,690	1,832,910
Medical sciences	897,376	950,907	1,128,652	1,237,556	1,414,345	1,599,203	1,717,072	1,801,576	1,989,803	2,259,525	2,578,240
Other life sciences	80,728	74,962	79,107	77,676	93,004	112,626	121,933	127,807	141,848	169,658	212,612
Psychology	77,888	85,133	89,664	100,531	111,290	128,328	132,322	138,505	146,884	162,047	180,453
Social sciences	262,261	268,087	277,497	295,138	341,445	370,351	358,286	354,348	372,337	389,790	459,303
Economics	65,447	72,124	79,129	83,089	90,158	99,496	95,590	96,476	109,215	115,789	132,377
Political science	28,355	32,314	36,571	45,431	55,395	56,315	61,371	55,545	56,317	60,738	68,074
Sociology	66,246	61,939	66,900	74,641	88,556	94,658	80,252	78,327	74,626	78,643	88,311
Other social sciences	102,213	101,710	94,897	91,977	107,336	119,882	121,073	124,000	132,178	134,620	170,542
Other sciences	100,532	105,724	116,478	133,592	146,118	144,330	152,180	162,037	176,433	182,066	220,311
Total engineering	431,727	498,473	601,062	768,407	864,924	960,677	1,025,513	1,110,811	1,207,104	1,386,717	1,609,093
Aeronautical and astronautical	NA	NA	NA	NA	46,285	45,481	60,226	65,009	66,344	75,716	86,519
Chemical	NA	NA	NA	NA	67,557	83,207	83,548	90,767	96,199	108,927	125,122
Civil	NA	NA	NA	NA	88,641	108,174	108,711	109,921	133,682	147,428	171,012
Electrical	NA	NA	NA	NA	184,050	193,080	223,862	259,283	291,795	336,932	398,203
Mechanical	NA	NA	NA	NA	146,163	149,128	142,171	149,881	176,682	205,625	224,206
Other engineering	NA	NA	NA	NA	332,228	381,607	406,995	435,950	442,391	512,088	604,031
Thousands of constant 1982 dollars											
Total	5,912,489	6,044,817	6,403,590	6,823,734	7,070,262	7,247,288	7,266,122	7,508,356	7,897,874	8,570,022	9,397,985
Total sciences	5,227,969	5,303,924	5,571,325	5,845,744	6,061,252	6,224,856	6,240,609	6,438,829	6,777,384	7,319,939	7,987,119
Physical sciences	601,521	629,395	687,343	766,074	790,122	813,828	822,584	863,758	920,744	1,019,981	1,105,985
Astronomy	41,690	48,099	50,930	61,676	68,525	71,666	73,237	71,420	74,684	81,901	84,467
Chemistry	222,201	236,850	253,574	262,722	284,627	302,149	308,091	322,225	341,449	370,257	403,406
Physics	290,233	299,725	325,532	371,685	375,910	379,799	365,897	398,772	435,722	494,778	545,634
Other physical sciences	47,397	44,721	57,307	69,990	61,060	60,215	75,359	71,340	68,890	73,045	72,478
Environmental sciences	457,477	474,729	525,327	576,448	593,838	584,206	557,817	595,598	602,990	634,485	678,805
Atmospheric	NA	NA	NA	NA	78,697	83,288	85,443	94,030	95,493	98,542	109,448
Earth sciences	NA	NA	NA	NA	219,582	201,886	195,507	208,125	209,343	225,361	229,591
Oceanography	NA	NA	NA	NA	200,266	199,514	197,701	215,669	221,068	234,151	241,582
Other environmental sciences	NA	NA	NA	NA	95,293	99,519	79,166	78,133	77,085	76,431	98,183
Mathematical sciences	67,371	77,753	81,357	99,882	91,772	94,501	98,568	104,023	115,472	116,757	133,454
Computer sciences	70,561	82,585	93,356	124,629	133,220	141,426	149,259	168,723	206,516	251,130	276,510
Life sciences	3,332,321	3,357,322	3,514,268	3,605,095	3,753,684	3,906,552	3,969,593	4,075,816	4,285,924	4,637,422	5,038,251
Agricultural sciences	654,617	684,672	722,438	766,813	793,140	822,088	844,040	862,238	863,497	925,204	984,097
Biological sciences	1,126,881	1,147,875	1,119,496	1,164,320	1,202,087	1,262,594	1,286,548	1,355,902	1,443,730	1,527,112	1,607,111
Medical sciences	1,422,825	1,413,358	1,562,797	1,575,100	1,649,959	1,702,004	1,717,072	1,734,620	1,847,028	2,032,495	2,260,623
Other life sciences	127,997	111,418	109,536	98,862	108,497	119,866	121,933	123,057	131,670	152,611	186,420
Psychology	123,495	126,535	124,154	127,951	129,830	136,577	132,322	133,357	136,345	145,765	158,223
Social sciences	415,825	398,465	384,238	375,637	398,326	394,158	358,286	341,179	345,621	350,625	402,721
Economics	103,769	107,200	109,567	105,752	105,177	105,892	95,590	92,890	101,378	104,155	116,069
Political science	44,958	48,029	50,638	57,822	64,623	59,935	61,371	53,481	52,276	54,635	59,688
Sociology	105,036	92,062	92,634	94,999	103,308	100,743	80,252	75,416	69,271	70,741	77,432
Other social sciences	162,063	151,174	131,400	117,064	125,217	127,588	121,073	119,391	122,694	121,094	149,533
Other sciences	159,397	157,140	161,282	170,029	170,460	153,608	152,180	156,015	163,773	163,773	193,171
Total engineering	684,520	740,893	832,265	977,990	1,009,011	1,022,432	1,025,513	1,069,527	1,120,490	1,247,384	1,410,866
Aeronautical and astronautical	NA	NA	NA	NA	53,996	48,405	60,226	62,593	61,584	68,108	75,861
Chemical	NA	NA	NA	NA	78,811	88,556	83,548	87,394	89,296	97,982	109,708
Civil	NA	NA	NA	NA	103,408	115,128	108,711	105,836	124,099	132,615	149,945
Electrical	NA	NA	NA	NA	214,711	205,492	223,862	249,647	270,858	303,078	349,148
Mechanical	NA	NA	NA	NA	170,512	158,714	142,171	144,311	164,004	184,964	196,586
Other engineering	NA	NA	NA	NA	387,573	406,138	406,995	419,748	410,648	460,635	529,619

Note: NA = not available

SOURCE: National Science Foundation, Academic Science and Engineering R&D Funds, 1985, and unpublished data

See figure O-24 in Overview

Science & Engineering Indicators—1987

**Appendix table 4-20. Research and development expenditures at universities and colleges,
by field and source of funds: 1986**

Field and source of funds	Total (Thousands of dollars)	Federal		Non-federal	
		(Thousands of dollars)	(Percent)	(Thousands of dollars)	(Percent)
		Thousands of dollars			
Total	\$10,718,402	\$6,633,347	61.9	\$4,085,055	38.1
Source of funds:					
Federal government	6,633,347	6,633,347	100.0	0	0.0
State and local governments	902,963	0	0.0	902,963	100.0
Industry	667,362	0	0.0	667,362	100.0
Institutional funds	1,774,421	0	0.0	1,774,421	100.0
Other source of funds	740,309	0	0.0	740,309	100.0
Fields:					
Total sciences	9,109,309	5,664,873	62.2	3,444,436	37.8
Physical sciences	1,261,376	975,516	77.3	285,859	22.7
Astronomy	96,335	64,009	66.4	32,326	33.6
Chemistry	460,084	337,913	73.4	122,171	26.6
Physics	622,296	509,574	81.9	112,722	18.1
Other physical sciences	82,661	64,021	77.5	18,640	22.5
Environmental sciences	774,177	520,137	67.2	254,039	32.8
Atmospheric	124,826	99,485	79.7	25,341	20.3
Earth sciences	261,849	150,942	57.6	110,906	42.4
Oceanography	275,524	207,095	75.2	68,429	24.8
Other environmental sciences	111,978	62,615	55.9	49,364	44.1
Mathematical sciences	152,204	112,364	73.8	39,840	26.2
Computer sciences	315,360	227,428	72.1	87,932	27.9
Life sciences	5,746,125	3,439,947	59.9	2,306,178	40.1
Agricultural sciences	1,122,363	298,075	26.6	824,288	73.4
Biological sciences	1,832,910	1,278,995	69.8	553,916	30.2
Medical sciences	2,578,240	1,738,382	67.4	839,858	32.6
Other life sciences	212,612	124,495	58.6	88,117	41.4
Psychology	180,453	118,449	65.6	62,004	34.4
Social sciences	459,303	166,948	36.3	292,355	63.7
Economics	132,377	42,878	32.4	89,499	67.6
Political science	68,074	19,731	29.0	48,343	71.0
Sociology	88,311	43,685	49.5	44,626	50.5
Other social sciences	170,542	60,655	35.6	109,887	64.4
Other sciences	220,311	104,083	47.2	116,228	52.8
Total engineering	1,609,093	968,474	60.2	640,619	39.8
Aeronautical and astronautical	86,519	67,345	77.8	19,174	22.2
Chemical	125,122	66,135	52.9	58,987	47.1
Civil	171,012	91,517	53.5	79,495	46.5
Electrical	398,203	265,885	66.8	132,317	33.2
Mechanical	224,206	144,529	64.5	79,677	35.5
Other engineering	604,031	333,063	55.1	270,968	44.9

SOURCE: National Science Foundation, *Academic Science and Engineering, R&D funds, 1986*, and unpublished data

Science & Engineering Indicators—1987

**Appendix table 4-21. Basic research expenditures in industry, by field:
1973-83**

Field	1973	1975	1977	1979	1981	1983
	Millions of dollars					
Total	\$631	\$730	\$911	\$1,158	\$1,614	\$2,104
Total sciences	446	538	677	865	1,156	1,422
Physical sciences	276	320	405	527	746	902
Chemistry	193	228	285	381	485	555
Mathematics	14	14	19	20	26	27
Environmental sciences	7	15	19	13	18	29
Atmospheric sciences	2	6	5	5	12	16
Geological sciences	3	5	7	6	6	13
Oceanography	1	3	7	2	0	0
Life sciences	102	122	156	177	208	276
Biological sciences	77	85	128	136	157	241
Clinical medical sciences	25	37	28	40	51	35
Other sciences	47	67	78	128	158	188
Total engineering	185	191	233	292	458	682
	Millions of constant 1982 dollars ¹					
Total	1,274	1,231	1,354	1,474	1,718	2,026
Total sciences	900	907	1,006	1,101	1,230	1,369
Physical sciences	557	540	602	671	794	868
Chemistry	390	384	424	485	516	534
Mathematics	28	24	28	25	28	26
Environmental sciences	14	25	28	17	19	28
Atmospheric sciences	4	10	7	6	13	15
Geological sciences	6	8	10	8	6	13
Oceanography	2	5	10	3	0	0
Life sciences	206	206	232	225	221	266
Biological sciences	155	143	190	173	167	232
Clinical medical sciences	50	62	42	51	54	34
Other sciences	95	113	116	163	168	181
Total engineering	373	322	346	372	487	657

¹ GNP implicit price deflator used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *Research and Development in Industry, 1984*, and unpublished data
Science & Engineering Indicators—1987

Appendix table 4-22. Plant and equipment expenditures in academic science and engineering, by source of funds: 1964-86

Years	Capital fund expenditures ¹						Current fund equipment expenditures ²	
	Total		Federal sources		Non-federal sources		Current dollars	Constant 1982 dollars
	Current dollars	Constant 1982 dollars	Current dollars	Constant 1982 dollars	Current dollars	Constant 1982 dollars		
Thousands of dollars								
1964	529,492	1,607,932	134,439	408,257	395,053	1,199,675	NA	NA
1965	NA	NA	NA	NA	NA	NA	NA	NA
1966	666,997	1,907,886	212,397	607,543	454,600	1,300,343	NA	NA
1967	NA	NA	NA	NA	NA	NA	NA	NA
1968	1,070,727	2,837,866	340,447	902,324	730,280	1,935,542	NA	NA
1969	NA	NA	NA	NA	NA	NA	NA	NA
1970	951,873	2,264,747	279,316	664,563	672,557	1,600,183	NA	NA
1971	NA	NA	NA	NA	NA	NA	NA	NA
1972	912,487	1,962,760	236,836	509,434	675,651	1,453,325	NA	NA
1973	835,862	1,687,247	224,651	453,474	611,211	1,233,773	NA	NA
1974	841,560	1,559,600	225,681	418,238	615,879	1,141,362	NA	NA
1975	1,018,773	1,717,709	270,083	455,375	748,690	1,262,334	NA	NA
1976	1,043,153	1,653,961	206,890	328,032	836,263	1,325,928	NA	NA
1977	960,014	1,426,894	195,519	290,605	764,495	1,136,289	NA	NA
1978	NA	NA	NA	NA	NA	NA	NA	NA
1979	696,218	886,112	164,460	209,317	531,758	676,795	NA	NA
1980	794,512	926,869	149,563	174,479	644,949	752,390	363,040	423,518
1981	952,672	1,013,912	153,800	163,687	798,872	850,226	413,972	440,583
1982	969,147	969,147	116,651	116,651	852,496	852,496	408,479	408,479
1983	1,098,941	1,058,098	131,517	126,629	967,424	931,469	435,178	419,004
1984	1,215,249	1,128,051	141,728	131,559	1,073,521	996,492	518,125	480,948
1985	1,312,657	1,180,765	144,296	129,798	1,168,361	1,050,968	654,652	588,875
1986	1,578,818	1,384,321	193,120	169,329	1,385,698	1,214,992	764,848	670,625

¹ Data includes expenditures from capital funds for facilities and equipment for research, development, and instruction.

² Data include funds spent from current operating funds for research equipment. These expenditures are not included in the "total expenditures" column.

Note: NA = not available.

SOURCES: National Science Foundation, *Academic Science Engineering: R&D Funds, Fiscal Year 1986, Detailed Statistical Tables* (forthcoming), and previous annual publications of the same name for earlier fiscal years.

See figure O-23 in Overview.

Science & Engineering Indicators—1987

Appendix table 4-23. Capital expenditures¹ at universities and colleges by field and source of funds: 1972-77 and 1979-86

Field	1972	1973	1974	1975	1976	1977 ²	1979	1980	1981	1982	1983	1984	1985	1986
Thousands of dollars														
Total	912,487	835,862	841,560	1,018,773	1,043,153	960,014	696,218	794,512	952,672	969,147	1,098,941	1,215,249	1,312,657	1,578,818
Engineering	84,950	55,800	91,701	118,315	81,678	87,718	87,128	89,297	103,329	144,457	134,980	142,894	187,320	316,440
Total sciences	827,537	780,062	749,859	900,458	961,475	872,296	609,090	705,215	849,343	824,690	963,961	1,072,355	1,125,337	1,262,378
Physical sciences	137,331	106,210	93,468	80,642	73,755	65,216	64,685	77,154	87,813	82,100	97,467	116,071	131,108	152,808
Environmental sciences	27,187	26,739	24,588	35,278	49,304	28,351	25,153	36,208	35,025	42,365	41,112	36,814	54,053	47,111
Mathematical/computer sciences	24,712	20,016	23,670	15,227	24,684	25,136	27,282	32,318	30,517	34,328	53,098	49,971	75,657	91,088
Life sciences	517,941	488,705	495,078	669,093	706,961	642,493	428,293	459,057	597,635	590,353	678,778	741,416	751,646	839,906
Psychology	19,007	39,584	15,511	11,710	9,131	12,702	7,060	17,982	10,991	12,798	17,012	35,205	20,900	25,472
Social sciences	59,993	61,215	59,329	50,904	44,303	31,798	21,358	35,073	45,138	30,797	40,870	51,933	61,849	50,711
Other sciences, N.E.C.	41,366	37,593	38,218	37,604	53,337	66,600	35,259	47,423	42,224	31,949	35,624	40,946	30,125	55,282
Federal sources	236,836	224,651	225,681	270,083	206,890	195,519	164,460	149,563	153,800	116,651	131,517	141,728	144,296	193,120
Engineering	21,082	13,547	42,702	64,019	20,200	17,219	20,927	20,438	17,601	18,136	16,163	24,013	16,778	33,635
Total sciences	215,754	211,104	182,979	206,064	186,690	178,300	143,533	129,125	136,199	98,515	115,354	117,715	127,519	159,485
Physical sciences	27,892	24,496	20,721	18,862	19,195	21,894	32,186	22,463	25,529	20,154	18,579	18,916	31,300	35,089
Environmental sciences	8,486	5,961	7,084	5,960	6,428	9,307	8,220	8,033	6,866	4,404	3,644	3,490	3,547	6,184
Mathematical/computer sciences	4,341	3,022	4,257	2,584	2,052	1,882	2,983	5,653	4,944	3,798	4,458	5,296	6,718	14,048
Life sciences	152,328	161,907	139,775	169,459	153,570	137,369	90,796	86,105	89,410	66,004	81,016	85,412	80,829	94,310
Psychology	3,663	5,119	2,536	2,245	1,967	2,398	1,740	2,002	1,580	1,023	1,365	1,008	820	1,266
Social sciences	10,939	5,369	4,467	2,755	1,806	2,109	2,076	1,528	6,376	1,374	4,959	2,932	2,096	2,505
Other sciences, N.E.C.	8,105	5,230	4,139	4,199	1,672	3,341	5,532	3,341	1,494	1,758	1,333	660	2,209	6,082
Other sources	675,651	611,211	615,879	748,690	836,263	764,495	531,758	644,949	798,872	852,496	967,424	1,073,521	1,168,361	1,385,698
Engineering	63,868	42,253	48,999	54,296	61,478	70,499	66,201	68,859	85,728	126,321	118,817	118,881	170,542	282,805
Total sciences	611,783	568,958	566,880	694,394	774,785	693,996	465,557	576,090	713,144	726,175	848,607	954,640	997,818	1,102,893
Physical sciences	109,439	81,714	72,747	61,780	54,560	43,322	32,499	54,691	62,284	61,946	78,888	97,154	99,808	117,719
Environmental sciences	18,701	20,778	17,504	29,318	42,876	19,044	16,933	28,175	28,159	37,961	37,468	33,324	50,506	40,927
Mathematical/computer sciences	20,371	16,994	19,413	12,643	22,632	23,254	24,299	26,665	25,573	30,530	48,640	44,675	68,939	77,040
Life sciences	365,613	326,798	355,303	499,634	553,391	505,124	337,497	372,952	508,225	524,349	597,762	656,004	670,817	745,596
Psychology	15,344	34,465	12,975	9,465	7,164	10,304	5,320	15,980	9,411	11,775	15,647	34,197	20,080	24,206
Social sciences	49,054	55,846	54,862	48,149	42,497	29,689	19,282	33,545	38,762	29,423	35,911	49,001	59,753	48,206
Other sciences, N.E.C.	33,261	32,363	34,076	33,405	51,665	63,259	29,727	44,082	40,730	30,191	34,291	40,286	27,916	49,200

Note: NA = Not available.

¹ Includes expenditures for facilities and equipment for research, development and instruction.

² Data were not collected in 1978.

SOURCE: National Science Foundation, *Academic Science and Engineering: R&D Funds 1986*

Appendix table 4-24. Academic officials' views regarding condition of research facilities: 1986

Field	Number of interviews	Condition of research facilities				
		Excellent	Good	Fair	Poor	Don't know ¹
		Percent				
Research administrators	80	4	44	45	4	4
Deans:						
Engineering	29	7	34	48	10	0
Physical sciences	39	0	31	51	10	8
Life sciences	39	8	38	41	10	3
Environmental sciences	33	3	21	52	21	3
Medical sciences	25	8	48	28	8	8
Computer sciences	37	14	32	41	14	0
Mathematical sciences	39	0	38	44	10	8
Psychology	38	3	37	26	24	11
Social sciences	39	5	33	44	15	3

¹ Some deans were unable to select one response, due primarily to variation in the condition of facilities in the discipline

SOURCE: National Science Foundation, *Science and Engineering Facilities at Doctorate-Granting Institutions*, September 1986

See figure 4-3.

Science & Engineering Indicators—1987

Appendix table 4-25. Academic officials' views on sufficiency of research space: 1986

Field	Number of interviews	Amount of research space		
		More than needed	About right	Less than needed
		Percent		
Research administrators	80	0	5	95
Deans:				
Engineering	29	0	7	93
Physical sciences	39	0	21	79
Life sciences	39	0	18	82
Environmental sciences	33	0	27	73
Medical sciences	25	0	28	72
Computer sciences	37	3	11	86
Mathematical sciences	39	3	33	64
Psychology	38	3	16	82
Social sciences	39	0	8	92

SOURCE: National Science Foundation, *Science and Engineering Research Facilities at Doctorate-Granting Institutions*, September 1986

See figure 4-4.

Science & Engineering Indicators—1987

Appendix table 4-26. Current fund expenditures for research equipment at universities and colleges, by field: 1980-86

Years	Total	Engineering	Physical science	Environmental science	Mathematical science	Computer science	Life science	Psychology	Social science	Other science
Thousands of dollars										
Total:										
1980	\$363,040	\$56,584	\$53,859	\$28,613	\$2,060	\$8,248	\$188,718	\$5,447	\$12,805	\$6,706
1981	413,972	69,017	76,131	31,472	1,907	10,896	202,220	6,019	9,155	7,155
1982 ¹	408,479	65,861	78,126	28,321	2,556	12,672	199,574	5,784	7,143	8,461
1983	435,178	75,018	79,375	31,521	2,668	15,615	205,680	6,629	8,961	9,711
1984	518,125	90,650	107,450	40,806	4,539	19,056	225,575	7,066	12,727	10,257
1985	654,652	119,246	141,884	46,990	5,755	38,667	269,862	8,465	8,929	14,853
1986	764,848	138,894	164,084	50,714	4,961	46,549	318,062	9,018	12,152	20,414
Federal:										
1980	240,816	35,804	44,453	19,512	1,439	3,434	122,385	4,126	6,391	3,272
1981	265,048	42,396	58,475	19,165	1,127	5,436	126,175	4,466	3,999	3,809
1982 ¹	266,780	43,220	62,642	18,423	1,617	8,215	120,189	4,219	2,907	5,306
1983	272,819	48,958	62,055	19,649	1,476	10,229	117,039	4,749	2,917	5,747
1984	335,495	59,278	86,746	29,477	3,213	14,056	128,837	5,016	3,484	5,387
1985	426,874	75,633	113,387	32,106	4,694	32,709	151,349	6,160	3,903	6,932
1986	496,664	80,992	133,410	35,431	3,405	39,226	182,722	6,055	3,779	11,644
Non-federal:										
1980	122,224	20,780	9,406	9,101	621	4,814	66,333	1,321	6,414	3,434
1981	148,924	26,612	17,656	12,307	780	5,460	76,045	1,553	5,156	3,346
1982 ^{1,2}	141,699	22,641	15,484	9,898	939	4,457	79,385	1,565	4,236	3,155
1983	162,359	26,060	17,320	11,872	1,192	5,386	88,641	1,880	6,044	3,964
1984	182,632	31,372	20,705	11,329	1,326	4,999	96,737	2,050	9,243	4,870
1985	227,778	43,613	28,496	14,884	1,061	5,958	118,513	2,305	5,026	7,921
1986	268,184	57,902	30,674	15,283	1,557	7,323	135,340	2,963	8,373	8,771

¹ 1982 total has been revised but breakdown has not.

² Estimated

SOURCE: National Science Foundation, *Academic Science Engineering: R&D Funds*, 1986

Science & Engineering Indicators—1987

Appendix table 4-27. Expenditures under special Federal research instrumentation programs: 1981-85

Fiscal year	Number of awards	Amount awarded	Mean size
Total	3,464	\$320,482	\$93
1981	274	16,853	62
1982	319	22,901	72
1983	702	72,123	103
1984	951	96,227	101
1985	1,218	112,378	92

SOURCE: Abt Associates Inc., "Federal government programs that support science and engineering research instrumentation in academic institutions," AAI Report No. 86-1, April 24, 1986

Science & Engineering Indicators—1987

Appendix table 4-28. Awards to colleges and universities under special Federal instrumentation programs, by R&D ranking of institutions

Rank group ²	Total FY 83 Federal R&D obligations		Total instrumentation awards (4 agencies) ¹		
	Thousands of dollars	Percent of total	Thousands of dollars	Percent of total	Number of awards
Total (1-641) ..	4,860,431	100.0	325,397	100.0	4,387
1-100	4,260,011	87.6	230,302	70.8	2,222
1-25	2,341,202	48.2	114,219	35.1	1,086
26-50	986,191	20.3	60,045	18.5	524
51-100	932,618	19.2	56,038	17.2	612
101-641	600,420	12.4	95,095	29.2	1,265

¹ Combines totals 1981 to 1985 of special instrumentation programs of National Science Foundation, National Institutes of Health, Department of Energy, and Department of Defense.

² Rank by total federal fiscal year 1983 research and development obligations.

SOURCE: Abt Associates Inc., "Federal government programs that support science and engineering research instrumentation in academic institutions," AAI Report No. 86-1, April 24, 1986.

See figure 4-5.

Science & Engineering Indicators—1987

Appendix table 4-29. Instrument needs, 1982/83, versus awards under special Federal instrumentation programs, 1981-85

Equipment type	Awards under special federal instrumentation programs: 1981-85			Instruments named by department chairmen as most needed: 1982/83	
	Number	Amount awarded	% of total	Number	Percent
Total	3,368	308,866	100.0	560	100.0
Computer	560	48,807	16.6	157	28.0
Laser	160	16,439	4.8	32	5.7
Sorters/sensors	69	4,790	2.0	8	1.4
Microscopes/other	45	3,973	1.3	10	1.8
Microscopes/electron	194	26,067	5.8	13	2.3
Temperature equipment	64	3,392	1.9	11	2.0
Spectrometers	701	78,377	20.8	95	17.0
Acquisition/detectors, receivers	312	25,561	9.3	41	7.3
Transmitters	16	1,588	0.5	9	1.6
Synthesis/preparation	89	6,340	2.6	5	0.9
Image processors	205	18,458	6.1	28	5.0
Separation technology	215	19,535	6.4	31	5.5
Vacuum	11	896	0.3	5	0.9
Hydraulic	10	1,032	0.3	6	1.1
Magnetic	18	1,202	0.5	7	1.3
Not identified	699	52,410	20.8	102	18.2

Note: Department chairmen were asked to name the three items of equipment in the \$10,000 to \$100,000 range which were most needed in their departments or facilities.

SOURCE: Abt Associates Inc., "Federal Government Programs that Support Science and Engineering Research Instrumentation in Academic Institutions," AAI Report No. 86-1, April 24, 1986.

See figure 4-6.

Science & Engineering Indicators—1987

Appendix table 4-30. Condition of academic research instrument systems, by system age

	Number and percent of systems, by general working condition			
	Total	Excellent	Average	Poor
Total	36,250 100%	18,849 52%	13,774 38%	3,627 10%
Age (from year of purchase): ¹				
1-5 years	19,351 100%	13,227 68%	5,396 28%	728 4%
6-10 years	8,747 100%	3,449 39%	4,226 48%	1,072 12%
Over 10 years	8,152 100%	2,172 27%	4,153 51%	1,827 22%

Note: All statistics are national estimates encompassing the 157 largest R&D universities and the 92 largest R&D medical schools in the nation. For agricultural, biological and environmental sciences, estimates are as of December 1983. For all other fields, estimates are as of December 1982. Sample is 7013 instrument systems.

Note: Subcategory numbers and percentages may not sum exactly to total because of rounding. Estimated totals may vary from table to table.

¹ For phase 2 fields, age intervals are 1-5 (1979-83); 6-10 years (1974-78); over 10 years (1973 or before). For phase 1 fields, intervals are 1-5 years (1978-82); 6-10 years (1973-77); over 10 years (1972 or before).

SOURCE: National Science Foundation, *Academic Research Equipment in Selected S/E Fields, 1982-83* (August 1985).

See figure 4-7.

Science & Engineering Indicators—1987

Appendix table 4-31. National stock of academic instrumentation, by field¹

Field	Instrument systems	Percent	Aggregate purchase price	Percent	Mean purchase price per system
Total	46,738	100.0	1,630,780	100.0	35
Engineering	9,425	20.0	333,613	20.0	35
Agricultural sciences	1,954	4.0	42,599	3.0	22
Biological sciences	17,618	38.0	471,288	29.0	27
Graduate schools	7,290	16.0	186,272	11.0	26
Medical schools	10,328	22.0	285,016	17.0	28
Computer sciences	1,115	2.0	60,026	4.0	54
Environmental sciences	2,679	6.0	126,231	8.0	47
Materials science	731	2.0	37,120	2.0	51
Physical sciences	11,644	25.0	481,881	30.0	41
Interdisciplinary, n.e.c.	1,571	3.0	78,022	5.0	50

Note: Subcategory numbers and percentages may not sum exactly to total because of rounding. Estimated totals may vary slightly from field to field.

¹ All statistics are national estimates encompassing the 157 largest R&D universities and the 92 largest R&D medical schools in the nation. For agricultural, biological and environmental sciences, estimates are as of December 1983. For all other fields, estimates are as of December 1982. Sample is 8704 instrument systems.

SOURCE: National Science Foundation, *Academic Research Equipment in Selected Science/Engineering Fields, 1982-83* (August 1985).

Science & Engineering Indicators—1987

Appendix table 4-32. Instrumentation-related expenditures in academic departments and facilities, by field

Field	Total	Percent	Purchase of research equipment		Purchase of research-related computer services		Maintenance/repair of research equipment	
			\$500 or more	Percent		Percent		Percent
Total	\$640.6	100.0	\$414.5	65.0	\$121.3	19.0	\$104.8	16.0
Engineering	146.6	100.0	86.5	59.0	41.3	28.0	18.8	13.0
Agricultural sciences	40.6	100.0	28.4	70.0	7.3	18.0	5.0	12.0
Biological sciences	192.3	100.0	132.4	69.0	27.8	14.0	32.2	17.0
Graduate schools	79.0	100.0	51.8	66.0	13.2	17.0	14.0	18.0
Medical schools	113.3	100.0	80.5	71.0	14.5	13.0	18.3	16.0
Computer science	29.7	100.0	19.7	66.0	3.6	12.0	6.4	21.0
Environmental sciences ..	49.6	100.0	33.4	67.0	6.9	14.0	9.3	19.0
Materials science	12.4	100.0	9.6	77.0	0.6	4.0	2.3	18.0
Physical science	151.3	100.0	91.2	60.0	31.9	21.0	28.2	19.0
Interdisciplinary, n.e.c.	17.8	100.0	13.3	75.0	1.9	11.0	2.6	14.0

Note: All statistics are national estimates encompassing the 157 largest R&D universities and the 92 largest R&D medical schools in the nation. For agricultural, biological and environmental sciences, estimates refer to expenditures in FY 1983. For all other fields, estimates are of expenditures in FY 1982. Sample is 912 departments and facilities.

Note: Subcategory numbers and percentages may not sum exactly to total because of rounding. Estimated totals may vary slightly from table to table.

SOURCE: National Science Foundation, *Academic Research Equipment in Selected Science Engineering Fields, 1982-83* (August 1985)

Science & Engineering Indicators—1987

Appendix table 4-33. Equipment-intensiveness of academic research, by field: 1982/3

Field	Total purchase price of national stock of academic research equipment (Millions of dollars)	Number of academic scientists and engineers January 1983	Total price of national stock per scientist and engineer
Total	1,516	107,000	14,200
Engineering	334	26,200	12,700
Chemical	27	2,100	12,900
Civil	22	4,400	5,000
Electrical	83	6,000	13,800
Mechanical	67	4,200	16,000
Other, n.e.c.	134	9,400	14,300
Agricultural sciences	43	14,100	3,000
Biological sciences	471	34,000	13,900
Computer sciences	60	6,300	9,500
Environmental sciences	120	7,000	18,000
Physical sciences	402	19,400	24,800
Chemistry	255	9,400	27,100
Physics and astronomy	227	10,000	22,700

SOURCE: National Science Foundation, *Academic Research Equipment in Selected Science Engineering Fields, 1982-83* (August 1985)

Science & Engineering Indicators—1987

**Appendix table 4-34. Instruments in shared-access facilities,
by status and field: 1982/3**

Field	Percent of systems in shared-access facilities		
	Total	Research status	
		State-of-the-art systems	Other systems in research use
Total	41	38	42
Engineering	50	50	49
Agricultural sciences	36	31	38
Biological sciences	35	32	36
Graduate schools	34	29	36
Medical schools	36	35	36
Computer sciences	81	73	83
Environmental sciences	48	46	49
Materials sciences	81	73	83
Physical sciences	35	27	37
Interdisciplinary, n.e.c.	73	84	68

SOURCE: National Science Foundation, *Academic Research Equipment In Selected Science Engineering Fields, 1982-83* (August, 1985)

Science & Engineering Indicators—1987

**Appendix table 4-35. Instruments in shared-access facilities, by status, age,
and field**

Field	Percent of systems in shared-access facilities			
	Total	System age (from year of purchase)		
		1-5 years	6-10 years	Over 10 years
Total	41	38	41	48
Engineering	50	41	51	73
Agricultural sciences	36	38	36	32
Biological sciences	35	31	35	42
Graduate schools	34	30	37	41
Medical schools	36	33	34	44
Computer sciences	81	80	87	100
Environmental sciences	48	51	48	40
Materials sciences	81	75	68	90
Physical sciences	35	31	40	37
Interdisciplinary, n.e.c.	73	67	78	73

SOURCE: National Science Foundation, *Academic Research Equipment In Selected Science Engineering Fields, 1982-83* (August 1985)

Science & Engineering Indicators—1987

**Appendix table 4-36. Institutional co-authorship, by field and selected years:
1973, 1977, 1981, and 1984**

Field	1973	1977	1981	1984
Institutionally co-authored articles as a percent of all articles				
Total fields	24.3	28.6	33.1	36.5
Clinical medicine	37.6	42.1	47.5	50.6
Biomedicine	25.7	30.1	34.4	38.5
Biology	19.4	22.7	26.7	30.2
Chemistry	14.9	18.3	21.3	23.8
Physics	19.3	23.5	26.7	29.9
Earth and space sciences	23.3	27.9	33.3	38.7
Engineering and technology ..	15.4	17.7	22.7	25.2
Mathematics	16.0	18.0	21.0	23.8
Institutionally co-authored articles				
Total fields	66,106	75,283	95,858	104,456
Clinical medicine	28,617	32,643	41,239	44,293
Biomedicine	10,648	12,436	15,839	17,371
Biology	4,660	5,405	6,875	7,689
Chemistry	6,694	7,485	9,986	10,800
Physics	6,897	8,433	10,651	12,092
Earth and space sciences	2,798	3,085	4,146	4,914
Engineering and technology ..	4,412	4,437	5,562	5,791
Mathematics	1,379	1,359	1,561	1,506
Articles with at least one institutional address				
Total fields	271,574	262,993	289,706	286,135
Clinical medicine	76,081	77,487	86,866	87,604
Biomedicine	41,370	41,314	46,052	45,161
Biology	24,064	23,761	25,707	25,492
Chemistry	45,002	40,905	46,807	45,440
Physics	35,791	35,897	39,919	40,418
Earth and space sciences	12,008	11,053	12,446	12,688
Engineering and technology ..	28,616	25,007	24,473	23,002
Mathematics	8,642	7,569	7,436	6,331

Note: Institutional co-authorship means that the address of more than one institution appears on the article.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 12, tabulations prepared for the National Science Foundation (January 1986).

See figure 5-11.

Science & Engineering Indicators—1987

Appendix table 4-37. Relative changes in Federal obligations for defense and nondefense R&D, by character of work: 1960-88

Year	Total			Basic research			Applied research			Development		
	Total	Defense	Nondefense	Total	Defense	Nondefense	Total	Defense	Nondefense	Total	Defense	Nondefense
Billions constant 1982 dollars ¹												
1967	46.0	22.4	23.6	5.1	0.8	4.3	7.8	3.6	4.1	33.1	18.0	15.1
1968	42.8	20.7	22.1	4.9	0.7	4.2	7.9	3.5	4.4	30.0	16.5	13.5
1969	39.9	19.6	20.3	5.0	0.7	4.3	6.9	2.9	4.0	28.1	16.0	12.0
1970	37.0	17.7	19.2	4.6	0.8	3.9	7.2	2.4	4.7	25.2	14.5	10.6
1971	35.6	17.2	18.4	4.5	0.7	3.8	7.2	2.3	4.9	23.9	14.2	9.7
1972	35.8	18.1	17.8	4.7	0.7	4.0	7.3	2.6	4.7	23.8	14.8	9.0
1973	34.7	17.4	17.4	4.6	0.6	4.0	6.9	2.3	4.6	23.2	14.4	8.8
1974	33.4	16.1	17.2	4.6	0.6	4.0	7.3	2.2	5.1	21.5	13.4	8.1
1975	33.1	15.7	17.4	4.5	0.5	4.0	7.2	2.0	5.2	21.4	13.2	8.2
1976	33.5	15.6	17.9	4.5	0.5	3.9	7.8	1.9	5.9	21.2	13.1	8.1
1977	35.0	16.4	18.6	4.9	0.6	4.3	7.8	2.0	5.8	22.3	13.8	8.5
1978	36.0	16.1	19.9	5.2	0.6	4.6	8.2	2.0	6.3	22.6	13.6	9.1
1979	36.1	16.1	20.1	5.4	0.6	4.8	8.1	2.0	6.2	22.6	13.5	9.1
1980	35.2	16.5	18.7	5.5	0.6	4.9	8.2	2.0	6.1	21.5	13.8	7.7
1981	35.5	17.7	17.8	5.4	0.6	4.8	7.7	2.1	5.6	22.4	14.9	7.5
1982	36.4	20.6	15.8	5.5	0.7	4.8	7.5	2.3	5.3	23.4	17.7	5.7
1983	37.1	22.1	15.1	6.0	0.8	5.3	7.7	2.3	5.3	23.5	19.0	4.5
1984	39.0	23.5	15.6	6.5	0.8	5.7	7.3	2.0	5.3	25.2	20.6	4.5
1985	43.3	26.7	16.6	7.0	0.8	6.2	7.4	2.1	5.4	28.8	23.8	5.0
1986 (Est.)	44.8	28.7	16.1	7.1	0.8	6.3	7.3	2.0	5.3	30.4	25.9	4.5
1987 (Est.)	47.8	30.7	17.1	7.5	0.7	6.7	7.6	2.0	5.6	32.7	28.0	4.8
1988 (Est.)	51.5	34.7	16.9	7.4	0.7	6.7	7.2	2.0	5.2	36.9	31.9	5.0

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *Federal Funds for Research and Development: Detailed Historical Tables: FY 1955-1986*, National Science Foundation, *Federal Funds for Research and Development, Fiscal Years 1986, 1987, and 1988*.

See figure O-6 in Overview

Science & Engineering Indicators—1987

Appendix table 5-1. Academic research and development and basic research by performer: 1960-87

Year	Nonacademic basic research					Academic research and development
	Total	Federal government	Industry	FFRDC's	Nonprofit institutions	
		Millions of dollars				
1960	\$1,410	\$160	\$376	\$97	\$131	\$646
1961	1,628	206	395	115	149	763
1962	1,969	251	488	136	190	904
1963	2,232	255	522	159	215	1,081
1964	2,561	314	549	191	232	1,275
1965	2,891	364	592	208	253	1,474
1966	3,226	385	624	227	275	1,715
1967	3,520	435	629	250	285	1,921
1968	3,796	432	642	276	297	2,149
1969	3,955	532	618	275	305	2,225
1970	4,088	577	602	269	305	2,335
1971	4,258	586	590	260	322	2,500
1972	4,437	625	593	244	345	2,630
1973	4,777	608	631	297	357	2,884
1974	5,108	696	699	285	405	3,023
1975	5,607	734	730	309	425	3,409
1976	6,157	786	819	359	464	3,729
1977	6,804	914	911	402	510	4,067
1978	7,841	1,029	1,035	567	585	4,625
1979	9,006	1,089	1,158	718	680	5,361
1980	10,113	1,182	1,325	786	760	6,060
1981	11,423	1,302	1,614	863	825	6,819
1982	12,356	1,465	1,880	870	865	7,276
1983	13,596	1,690	2,171	983	945	7,807
1984	14,941	1,861	2,515	1,052	1,010	8,503
1985	16,349	1,961	2,731	1,078	1,075	9,504
1986 (Est.)	17,809	2,000	2,959	1,150	1,100	10,600
1987 (Est.)	18,595	2,000	3,125	1,200	1,120	11,150
Millions of constant 1982 dollars ¹						
1960	4,556	517	1,215	313	423	2,087
1961	5,211	659	1,264	368	477	2,442
1962	6,165	786	1,528	426	595	2,830
1963	6,889	787	1,611	491	664	3,336
1964	7,777	954	1,667	580	705	3,872
1965	8,558	1,078	1,753	616	749	4,364
1966	9,228	1,101	1,785	649	787	4,906
1967	9,794	1,210	1,750	696	793	5,345
1968	10,061	1,145	1,702	732	787	5,696
1969	9,942	1,337	1,554	691	767	5,593
1970	9,726	1,373	1,432	640	726	5,556
1971	9,594	1,320	1,329	586	726	5,633
1972	9,544	1,344	1,276	525	742	5,657
1973	9,643	1,227	1,274	600	721	5,822
1974	9,466	1,290	1,295	528	751	5,602
1975	9,454	1,238	1,231	521	717	5,748
1976	9,762	1,246	1,299	569	736	5,912
1977	10,113	1,359	1,354	598	758	6,045
1978	10,857	1,425	1,433	785	810	6,404
1979	11,462	1,386	1,474	914	865	6,823
1980	11,798	1,379	1,546	917	887	7,070
1981	12,157	1,386	1,718	918	878	7,257
1982	12,356	1,465	1,880	870	865	7,276
1983	13,091	1,627	2,090	946	910	7,517
1984	13,869	1,727	2,335	977	938	7,893
1985	14,706	1,764	2,457	970	967	8,549
1986 (Est.)	15,615	1,754	2,594	1,008	964	9,294
1987 (Est.)	15,777	1,697	2,651	1,018	950	9,460

(continued)

Appendix table 5-1 (continued)

Year	Total	Nonacademic basic research				Academic research and development
		Federal government	Industry	FFRDC's	Nonprofit Institutions	
		Percent				
1960	100.0	11.3	26.7	6.9	9.3	45.8
1961	100.0	12.7	24.3	7.1	9.2	46.9
1962	100.0	12.7	24.8	6.9	9.6	45.9
1963	100.0	11.4	23.4	7.1	9.6	48.4
1964	100.0	12.3	21.4	7.5	9.1	49.8
1965	100.0	12.6	20.5	7.2	8.8	51.0
1966	100.0	11.9	19.3	7.0	8.5	53.2
1967	100.0	12.4	17.9	7.1	8.1	54.6
1968	100.0	11.4	16.9	7.3	7.8	56.6
1969	100.0	13.5	15.6	7.0	7.7	56.3
1970	100.0	14.1	14.7	6.6	7.5	57.1
1971	100.0	13.8	13.9	6.1	7.6	58.7
1972	100.0	14.1	13.4	5.5	7.8	59.3
1973	100.0	12.7	13.2	6.2	7.5	60.4
1974	100.0	13.6	13.7	5.6	7.9	59.2
1975	100.0	13.1	13.0	5.5	7.6	60.8
1976	100.0	12.8	13.3	5.8	7.5	60.6
1977	100.0	13.4	13.4	5.9	7.5	59.8
1978	100.0	13.1	13.2	7.2	7.5	59.0
1979	100.0	12.1	12.9	8.0	7.6	59.5
1980	100.0	11.7	13.1	7.8	7.5	59.9
1981	100.0	11.4	14.1	7.6	7.2	59.7
1982	100.0	11.9	15.2	7.0	7.0	58.9
1983	100.0	12.4	16.0	7.2	7.0	57.4
1984	100.0	12.5	16.8	7.0	6.8	56.9
1985	100.0	12.0	16.7	6.6	6.6	58.1
1986 (Est.)	100.0	11.2	16.6	6.5	6.2	59.5
1987 (Est.)	100.0	10.8	16.8	6.5	6.0	60.0

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources, 1987* (forthcoming)

Science & Engineering Indicators—1987

Appendix table 5-2. Basic research expenditures by performer, for selected countries

Performer	United States	Japan	Germany ¹	France ¹	United Kingdom
	Percent				
Total	100	100	100	100	100
Higher education	57	61	60	67	55
Industry	19	26	18	9	13
Government ²	16	11	22	22	30
Private nonprofit	8	2	1	3	2

Note: Data is for a year in the 1980-84 period depending upon the country. Data for Japan, West Germany and France include the natural sciences and engineering, the social sciences and the humanities; the United States data exclude the humanities; the U.K. data excludes the social sciences and the humanities.

¹ In France, CNRS R&D is classified as higher education in performance data but as government in source-of-funds data; in West Germany the Max Planck Institutes are classified as government.

² In the U.S., the government sector is federal only; in other countries, government includes all levels.

SOURCE: National Science Foundation; Organisation for Economic Co-operation and Development (OECD); and unpublished estimates.

See figure 5-1.

Science & Engineering Indicators—1987

Appendix table 5-3. Scientists and engineers in academic research and development and basic research:¹ 1986

Field	Business & industry		Education		Nonprofit		Federal Government ²		All institutions	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	13,100	6.1	168,900	79.2	9,400	4.4	17,200	8.1	213,300	100.0
Total scientists	9,400	5.4	138,300	78.7	9,100	5.2	14,500	8.3	175,700	100.0
Physical scientists	3,900	12.0	20,400	62.8	1,200	3.7	5,600	17.2	32,500	100.0
Chemists	2,400	17.3	9,400	67.6	200	1.4	1,600	11.5	13,900	100.0
Physicists/astronomers	1,400	8.8	9,600	60.4	1,000	6.3	3,000	18.9	15,900	100.0
Other physical scientists	100	3.4	1,500	51.7	NA	NA	1,000	34.5	2,900	100.0
Environmental scientists	1,400	10.9	8,200	64.1	300	2.3	2,300	18.0	12,800	100.0
Atmospheric scientists	NA	NA	1,500	68.2	100	4.5	400	18.2	2,200	100.0
Earth scientists	1,200	13.8	5,100	58.6	NA	NA	1,900	21.8	8,700	100.0
Oceanographers	NA	NA	1,600	84.2	300	15.8	100	5.3	1,900	100.0
Mathematical scientists	100	1.4	5,300	72.6	NA	NA	200	2.7	7,300	100.0
Computer specialists	500	6.9	6,200	86.1	300	4.2	200	2.8	7,200	100.0
Life scientists	2,300	2.7	67,800	80.8	6,400	7.6	5,500	6.6	83,900	100.0
Agricultural scientists	200	1.4	13,500	91.2	NA	NA	900	6.1	14,800	100.0
Biological scientists	2,100	3.6	45,100	76.7	5,600	9.5	4,400	7.5	58,800	100.0
Medical scientists	NA	NA	9,200	89.3	900	8.7	200	1.9	10,300	100.0
Psychologists	400	3.2	11,400	90.5	400	NA	200	1.6	12,600	100.0
Social scientists	900	4.6	17,400	89.2	400	2.1	500	2.6	19,500	100.0
Economists	400	4.8	7,300	88.0	300	3.6	300	3.6	8,300	100.0
Sociologists/anthropologists	400	6.6	5,200	85.2	100	1.6	100	1.6	6,100	100.0
Other social scientists	NA	NA	5,000	98.0	NA	NA	NA	NA	5,100	100.0
Total engineers	3,700	9.8	30,600	81.0	200	0.5	2,700	7.1	37,800	100.0
Aeronautical and astronautical	300	11.1	1,400	51.9	NA	NA	1,000	37.0	2,700	100.0
Chemical	600	18.2	2,600	78.8	100	3.0	NA	NA	3,300	100.0
Civil	300	9.7	2,300	74.2	NA	NA	200	NA	3,100	100.0
Electrical/electronics	700	6.5	9,200	85.2	200	NA	600	5.6	10,800	100.0
Industrial	100	14.3	600	85.7	NA	NA	NA	NA	700	100.0
Materials	300	13.0	1,900	82.6	NA	NA	NA	NA	2,300	100.0
Mechanical	900	13.2	5,700	83.8	NA	NA	200	2.9	6,800	100.0
Mining	NA	NA	200	66.7	NA	NA	NA	NA	300	100.0
Nuclear	NA	NA	400	100.0	NA	NA	100	25.0	400	100.0
Petroleum	NA	NA	300	75.0	NA	NA	NA	NA	400	100.0
Other engineers	500	7.1	6,100	87.1	NA	NA	300	4.3	7,000	100.0

Note: NA = Not available.

¹ Data include S.E.s whose primary work activity is basic research or, in educational institutions, research and development.

² S.E.s whose primary work activity is military have been included with Federal Government.

SOURCE: National Science Foundation, Surveys of Science Resources Series, *U.S. Scientists and Engineers, 1986*.

See figures 5-2 and 5-5.

Science & Engineering Indicators—1987

**Appendix table 5-4. Ph.D. scientists and engineers in academic research and development and basic research:¹
1985**

Field	Business & industry		Education		Nonprofit		Federal Government ²		All institutions	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	6,820	8.7	60,739	77.3	3,447	4.4	6,293	8.0	78,570	100.0
Total scientists	6,211	8.6	55,550	76.9	3,392	4.7	5,726	7.9	72,200	100.0
Physical scientists	3,377	20.7	10,695	65.4	843	5.2	1,357	8.3	16,341	100.0
Chemists	2,520	29.7	5,072	59.9	225	2.7	605	7.1	8,474	100.0
Physicists/astronomers	857	10.9	5,623	71.5	618	7.9	752	9.6	7,867	100.0
Environmental scientists	341	7.9	2,701	62.5	290	6.7	927	21.5	4,320	100.0
Atmospheric scientists	45	4.7	606	63.1	144	15.0	161	16.7	963	100.0
Earth scientists	263	11.3	1,335	57.2	78	3.3	604	25.9	2,334	100.0
Oceanographers	33	3.2	758	74.1	68	6.6	162	15.8	1,023	100.0
Mathematical scientists	154	5.9	2,396	91.1	44	1.7	36	1.4	2,630	100.0
Computer specialists	180	10.6	1,438	84.6	10	0.6	71	4.2	1,699	100.0
Life scientists	2,064	5.5	29,150	78.0	1,951	5.2	3,199	8.6	37,372	100.0
Agricultural scientists	101	2.0	4,271	84.8	53	1.1	552	11.0	5,034	100.0
Biological scientists	1,666	6.3	20,017	75.3	1,854	7.0	2,422	9.1	26,600	100.0
Medical scientists	297	5.2	4,862	84.7	179	3.1	225	3.9	5,738	100.0
Psychologists	55	1.4	3,607	93.7	89	2.3	56	1.5	3,849	100.0
Social scientists	40	0.7	5,563	93.7	165	2.8	80	1.3	5,939	100.0
Economists	10	0.4	2,344	99.3	0	0.0	7	0.3	2,361	100.0
Sociologists/anthropologists	3	0.2	1,336	95.6	54	3.9	0	0.0	1,398	100.0
Other social scientists	27	1.2	1,883	86.4	111	5.1	73	3.3	2,180	100.0
Total engineers	609	9.5	5,189	80.8	55	0.9	567	8.8	6,420	100.0
Aeronautical and astronautical	16	3.9	252	61.5	2	0.5	140	34.1	410	100.0
Chemical	69	10.1	566	82.9	0	0.0	48	7.0	683	100.0
Civil	32	5.3	571	94.7	0	0.0	0	0.0	603	100.0
Electrical/electronics	108	12.1	781	87.9	0	0.0	0	0.0	889	100.0
Materials	166	18.9	488	55.5	48	5.5	177	20.1	879	100.0
Mechanical	24	3.5	619	90.4	0	0.0	42	6.1	685	100.0
Nuclear	28	9.6	263	90.4	0	0.0	0	0.0	291	100.0
Systems design engineers	16	8.0	178	89.4	5	2.5	0	0.0	199	100.0
Other engineers	150	8.4	1,471	82.6	0	0.0	160	9.0	1,781	100.0

¹ Data include S/E's whose primary work activity is basic research or, in educational institutions, research and development.

² S/E's whose primary work activity is military have been included with Federal Government.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1985*

See figure 5-6.

Science & Engineering Indicators—1987

Appendix table 5-5. Doctoral scientists and engineers in research,¹ by gender: 1975 and 1985

Sector	Total	Male	Female	Male	Female
1975					
				Percent	
Total	110,765	100,660	10,105	90.9	9.1
4-year universities and colleges	99,226	90,182	9,044	90.9	9.1
Business and industry	4,273	4,024	249	94.2	5.8
Other non-profit	2,238	1,908	330	85.3	14.7
Federal government	4,679	4,267	412	91.2	8.8
State and local governments	349	279	70	79.9	20.1
1985					
				Percent	
Total	137,608	117,458	20,150	85.4	14.6
4-year universities and colleges	120,691	102,731	17,960	85.1	14.9
Business and industry	6,820	6,135	685	90.0	10.0
Other non-profit	3,447	2,736	711	79.4	20.6
Federal government	6,189	5,456	733	88.2	11.8
State and local governments	461	400	61	86.8	13.2

¹ Data include doctoral S.E.s whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development.

SOURCE: National Academy of Sciences, Survey of Doctoral Recipients (special tabulations prepared for the National Science Foundation, 1986)

See figure 5-3.

Science & Engineering Indicators—1987

Appendix table 5-6. Doctoral scientists and engineers in research¹ by race and type of employer: 1975 and 1985

Sector	Total	White	Black	Asian	Other
1975					
Total	110,765	100,524	874	6,310	3,057
4-year universities and colleges	99,226	90,211	755	5,459	2,801
Business and industry	4,273	3,772	19	373	109
Other non-profit	2,238	1,920	13	239	66
Federal government	4,679	4,303	83	222	71
State and local governments	349	318	4	17	10
1985					
Total	137,147	122,602	1,606	12,331	1,069
4-year universities and colleges	120,691	107,809	1,466	10,522	894
Business and industry	6,820	5,786	64	888	82
Other non-profit	3,447	2,954	6	457	30
Federal government	6,189	5,594	70	462	63
State and local governments	NA	459	NA	2	NA

¹ Data include doctoral S.E.s whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development.

SOURCE: National Academy of Sciences, Survey of Doctoral Recipients (special tabulations prepared for the National Science Foundation, 1986)

See figure 5-4.

Science & Engineering Indicators—1987

Appendix table 5-7. Foreign recipients of U.S. doctoral degrees¹ with postgraduation plans, by field of science: 1972 & 1986

Fields	Doctorate recipients with firm plans					Doctorate recipients with firm plans in U.S.		
	Total	Total	U.S.	Abroad	Study ^a	Employment		
						Academic	Industrial	Other
Doctoral recipients — 1972								
Total science engineering fields	2,169	1,397	408	989	251	94	30	30
Physical sciences	387	240	105	135	94	6	4	0
Physics astronomy	209	132	64	68	56	4	3	0
Chemistry	178	108	41	67	38	2	1	0
Earth, environmental & marine sciences	64	43	10	33	4	3	1	2
Mathematical sciences	169	102	42	60	16	22	2	2
Computer science	NA	NA	NA	NA	NA	NA	NA	NA
Life sciences	537	359	83	276	71	7	2	1
Biological sciences	305	205	70	135	61	5	1	1
Agricultural sciences	232	154	13	141	10	2	1	0
Social sciences	415	314	62	252	9	33	0	20
Psychology	78	48	13	35	2	9	1	1
Engineering	519	291	93	198	55	14	20	4
Doctoral recipients — 1986								
Total science engineering fields	4,051	2,617	1,371	1,040	744	365	233	29
Physical sciences	758	497	344	109	294	23	24	3
Physics astronomy	365	248	165	63	137	12	15	1
Chemistry	393	249	179	46	157	11	9	2
Earth, environmental & marine sciences	106	71	32	37	24	4	3	1
Mathematical sciences	272	194	123	54	48	71	3	1
Computer science	122	84	59	22	9	31	18	1
Life sciences	711	493	187	272	162	14	9	2
Biological sciences	391	275	146	108	132	9	3	2
Agricultural sciences	320	218	41	164	30	5	6	0
Social sciences	633	414	115	268	18	85	4	8
Psychology	80	44	16	25	8	7	0	1
Engineering	1,369	820	495	253	181	130	172	12
Percent of all foreign recipients with firm plans — 1972								
Total science engineering fields	100	29.2	70.8	18.0	6.7	2.1	2.1	
Physical sciences	100	43.8	56.3	39.2	2.5	1.7	0.0	
Physics astronomy	100	48.5	51.5	42.4	3.0	2.3	0.0	
Chemistry	100	38.0	62.0	35.2	1.9	0.9	0.0	
Earth, environmental & marine sciences	100	23.3	76.7	9.3	7.0	2.3	4.7	
Mathematical sciences	100	41.2	58.8	15.7	21.6	2.0	2.0	
Computer science	NA	NA	NA	NA	NA	NA	NA	
Life sciences	100	23.1	76.9	19.8	1.9	0.6	0.3	
Biological sciences	100	34.1	65.9	29.8	2.4	0.5	0.5	
Agricultural sciences	100	8.4	91.6	6.5	1.3	0.6	0.0	
Social sciences	100	19.7	80.3	2.9	10.5	0.0	6.4	
Psychology	100	27.1	72.9	4.2	18.8	2.1	2.1	
Engineering	100	32.0	68.0	18.9	4.8	6.9	1.4	
Percent of all foreign recipients with firm plans—1986								
Total science engineering fields	100	52.4	39.7	28.4	13.9	8.9	1.1	
Physical sciences	100	69.2	21.9	59.2	4.6	4.8	0.6	
Physics astronomy	100	66.5	25.4	55.2	4.8	6.0	0.4	
Chemistry	100	71.9	18.5	63.1	4.4	3.6	0.8	
Earth, environmental & marine sciences	100	45.1	52.1	33.8	5.6	4.2	1.4	
Mathematical sciences	100	63.4	27.8	24.7	36.6	1.5	0.5	
Computer science	100	70.2	26.2	10.7	36.9	21.4	1.2	
Life sciences	100	37.9	55.2	32.9	2.8	1.8	0.4	
Biological sciences	100	53.1	39.3	48.0	3.3	1.1	0.7	
Agricultural sciences	100	18.8	75.2	13.8	2.3	2.8	0.0	
Social sciences	100	27.8	64.7	4.3	20.5	1.0	1.9	
Psychology	100	36.4	56.8	18.2	15.9	0.0	2.3	
Engineering	100	60.4	30.9	22.1	15.9	21.0	1.5	

Note NA = not available.

¹ Excludes foreign doctorate recipients holding U.S. permanent residence visas.

² Includes postdoctoral research assistants.

SOURCE: National Research Council, Office of Scientific and Engineering Personnel, Doctorate Records File, special tabulations.

Science & Engineering Indicators—1987

Appendix table 5-8. Proportion of Ph.D. researchers¹ who remained employed in sector: 1973-85

Years ²	Employment sectors			
	Business and industry	4 year colleges and universities	Nonprofit institutions	Federal Government
	Percent			
All fields:				
1973-75	96.0	96.4	67.3	82.2
1975-77	96.4	95.4	76.4	90.3
1977-79	95.5	94.3	78.5	91.8
1979-81	96.5	95.2	77.3	93.0
1981-83	95.4	94.8	66.6	93.3
1983-85	96.5	95.6	75.5	89.3
Scientists:				
1973-75	96.2	96.4	68.6	82.4
1975-77	96.8	95.3	73.8	89.7
1977-79	95.0	94.6	78.4	92.2
1979-81	96.1	95.3	73.6	92.9
1981-83	96.1	94.7	67.1	93.0
1983-85	95.8	95.4	74.2	89.6
Engineers:				
1973-75	95.5	95.8	60.3	81.1
1975-77	95.5	96.8	94.5	95.0
1977-79	96.9	91.9	79.8	88.3
1979-81	97.7	94.2	93.2	93.8
1981-83	93.9	96.2	64.6	97.2
1983-85	98.1	96.9	82.8	87.5

¹ Data include doctoral S E's whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development.

² The survey instrument is collected biennially. The proportions shown are those giving the same answer to the sector-of-employment question in the second year of the range as they did in the first year.

SOURCE: National Academy of Sciences, Survey of Doctoral Recipients (special tabulations prepared for the National Science Foundation, 1986)

See figure 5-9.

Science & Engineering Indicators—1987

Appendix table 5-9. Scientists and engineers in academic research and development and basic research:¹ 1976-1986

Field	1976	1978	1980	1982	1984	1986
Total	92,900	105,900	127,200	150,500	188,200	213,300
Total scientists	79,200	93,800	110,600	129,400	156,300	175,700
Physical scientists	21,700	23,600	24,900	26,800	27,400	32,500
Chemists	9,500	10,200	11,300	12,300	11,900	13,900
Physicists/astronomers	10,700	10,700	10,800	10,800	12,700	15,900
Other physical scientists	1,600	2,800	2,700	3,600	2,900	2,900
Environmental scientists	6,700	6,800	7,800	9,100	12,400	12,800
Atmospheric scientists	1,300	1,900	1,900	2,500	3,100	2,200
Earth scientists	5,300	3,300	4,300	5,300	8,300	8,700
Oceanographers	200	1,700	1,600	1,400	1,000	1,900
Mathematical scientists	2,300	3,000	3,500	4,000	5,300	7,300
Computer specialists	1,200	2,200	2,300	2,800	6,000	7,200
Life scientists	33,400	44,600	55,600	66,800	74,300	83,900
Agricultural scientists	4,700	6,600	8,200	10,500	12,000	14,800
Biological scientists	23,400	28,900	38,300	47,600	53,700	58,800
Medical scientists	5,500	9,300	9,200	8,600	8,600	10,300
Psychologists	4,000	4,900	6,000	6,300	10,900	12,600
Social scientists	9,900	8,700	10,500	13,600	20,300	19,500
Economists	2,100	2,000	3,200	5,300	7,900	8,300
Sociologists/anthropologists	4,300	3,800	4,600	5,300	5,200	6,100
Other social scientists	3,500	2,900	2,700	3,000	7,100	5,100
Total engineers	13,600	12,000	16,500	21,100	31,800	37,800
Aeronautical and astronautical	1,200	400	900	NA	NA	2,700
Chemical	500	700	1,200	1,400	2,200	3,300
Civil	1,800	1,000	1,500	1,500	2,500	3,100
Electrical/electronics	3,300	3,500	4,800	7,000	8,400	10,800
Industrial	NA	NA	NA	400	500	700
Materials	NA	NA	NA	1,300	2,500	2,300
Mechanical	2,300	1,800	2,400	3,200	6,700	6,800
Mining	NA	NA	NA	300	500	300
Nuclear	NA	NA	NA	400	500	400
Petroleum	NA	NA	NA	400	NA	400
Other engineers	4,300	4,600	5,900	4,000	6,500	7,000

Note: NA = Not available

¹ Includes scientists and engineers whose primary work activity is basic research or, in 4-year colleges and universities, research and development

SOURCE: National Science Foundation, *U.S. Scientists and Engineers, 1986*

See figure 5-7.

Science & Engineering Indicators—1987

Appendix table 5-10. Ph.D. scientists and engineers in academic research and development and basic research:¹ 1977-1985

Field	1977	1979	1981	1983	1985
Total	56,123	61,468	70,004	72,329	78,570
Total scientists	51,926	56,767	64,694	66,245	72,200
Physical scientists	13,887	13,973	15,818	15,873	16,341
Chemists	7,558	7,413	8,686	8,242	8,474
Physicists/astronomers	6,329	6,560	7,132	7,631	7,867
Environmental scientists	3,021	3,341	4,024	3,851	4,320
Atmospheric scientists	569	730	812	871	963
Earth scientists	1,788	1,935	2,279	2,119	2,334
Oceanographers	664	676	933	861	1,023
Mathematical scientists	2,154	2,447	2,121	2,159	2,630
Computer specialists	598	756	1,061	1,165	1,699
Life scientists	24,706	28,383	33,530	34,238	37,372
Agricultural scientists	3,749	3,921	4,719	4,382	5,034
Biological scientists	17,149	19,451	22,888	24,664	26,600
Medical scientists	3,808	5,011	5,923	5,192	5,738
Psychologists	2,848	3,599	3,649	3,439	3,849
Social scientists	4,712	4,268	4,491	5,520	5,939
Economists	1,216	1,217	1,321	2,051	2,361
Sociologists/anthropologists	1,386	1,331	1,422	1,553	1,398
Other social scientists	2,110	1,720	1,748	1,916	2,180
Total engineers	4,197	4,701	5,310	6,084	6,420
Aeronautical and astronautical	NA	NA	316	451	410
Chemical	NA	NA	433	492	683
Civil	NA	NA	445	492	603
Electrical/electronics	NA	NA	700	822	889
Materials	NA	NA	735	1,180	879
Mechanical	NA	NA	540	345	685
Nuclear	NA	NA	299	339	291
Systems design	NA	NA	358	203	199
Other engineers	NA	NA	1,484	1,760	1,781

Note: NA = Not available.

¹ Includes scientists and engineers whose primary work activity is basic research or, in 4-year colleges and universities, research and development.

SOURCE: National Science Foundation, *Characteristics of Doctoral Scientists and Engineers in the United States, 1985*

See figure 5-8.

Science & Engineering Indicators—1987

Appendix table 5-11. Proportion of Ph.D. researchers employed in nonprofits and government who moved to other sectors: 1973-85

Year ² and field	Mobility from nonprofits to:			Mobility from government to:		
	Business and industry	Colleges and universities	Federal Government	Business and industry	Colleges and universities	Nonprofit institutions
	Percent					
All fields:						
1973-75	5.4	22.1	3.8	3	10.6	1.8
1975-77	3.6	14.1	2.5	1.8	4	2
1977-79	4.7	12.9	1.3	0.9	3.3	1.3
1979-81	4.0	10.6	6.5	2.4	2.8	0.3
1981-83	18.5	11.4	1.5	3	2.4	0.5
1983-85	10.4	11.3	1.4	2	4.9	1.4
Scientists:						
1973-75	4.9	21.4	3.8	2.7	10.4	1.7
1975-77	3.7	16.1	2.5	1.7	4.2	2.3
1977-79	3.6	13.7	1.4	1	3.7	0.9
1979-81	4.9	11.6	8.0	2.4	2.7	0.3
1981-83	15.0	13.6	1.9	3.3	2.5	0.5
1983-85	9.6	12.9	1.6	1.7	5	0.5
Engineers:						
1973-75	8.3	25.9	NA	4.6	11.9	2.4
1975-77	2.8	NA	NA	2.3	2.7	NA
1977-79	13.9	6.4	0.2	NA	NA	5.2
1979-81	NA	6.5	NA	1.9	3.6	0.6
1981-83	0.8	1.5	2.8	NA	1.4	1.4
1983-85	15.2	1.9	3.7	4.4	4.7	3.3

¹ Data include doctoral S.E.s whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development

² The survey data are collected biennially

SOURCE: National Academy of Sciences, Survey of Doctoral Recipients (special tabulations prepared for the National Science Foundation, 1986)

Science & Engineering Indicators—1987

Appendix table 5-12. Proportion of Ph.D. researchers¹ who moved between university and industry: 1973-85

Year ² and field	From universities and colleges to business and industry	From business and industry to universities and colleges
	Percent	
All fields:		
1973-75	1.7	1.8
1975-77	1.8	2.1
1977-79	2.4	2.3
1979-81	2.5	2.1
1981-83	2.8	2.8
1983-85	2.3	1.6
Scientists:		
1973-75	1.7	1.8
1975-77	1.8	2.0
1977-79	2.2	2.0
1979-81	2.5	2.1
1981-83	2.8	2.1
1983-85	2.3	2.2
Engineers:		
1973-75	2.4	2.8
1975-77	2.3	2.4
1977-79	4.4	3.1
1979-81	3.4	2.2
1981-83	2.6	4.4
1983-85	1.6	0.1

¹ Doctoral S-Es in industry whose primary or secondary work activity is basic research or, in 4-year colleges and universities, research and development.

² The survey data are collected biennially.

SOURCE: National Academy of Sciences, *Survey of Doctoral Recipients* (special tabulations prepared for the National Science Foundation, 1986)

Science & Engineering Indicators—1987

Appendix table 5-13. Cross-sectoral institutional coauthorship: 1973, 1977, 1981, and 1984

Sectors ²	Articles ¹				Percent			
	1973	1977	1981	1984	1973	1977	1981	1984
Participation in industry articles:								
University	1,603	1,631	2,310	2,877	13.1	15.3	20.1	24.3
Nonprofit	164	140	225	351	1.3	1.3	2.0	3.0
FFRDC's	106	133	199	309	0.9	1.2	1.7	2.6
Government	433	463	563	762	3.5	4.4	4.9	6.4
Participation in nonprofit articles:								
University	4,570	4,689	5,831	6,093	45.3	47.9	51.3	53.0
Industry	164	140	225	351	1.6	1.4	2.0	3.1
FFRDC's	38	48	75	104	0.4	0.5	0.7	0.9
Government	716	743	876	857	7.1	7.6	7.7	7.5
Participation in FFRDC articles:								
University	1,408	1,485	1,811	1,879	29.7	31.3	32.5	37.3
Industry	106	133	199	309	2.2	2.8	3.6	6.1
Nonprofits	38	48	75	104	0.8	1.0	1.3	2.1
Government	110	136	208	263	2.3	2.9	3.7	5.2
Participation in Federal Government articles:								
University	6,372	6,816	7,957	8,228	35.0	40.8	45.4	47.6
Industry	433	463	563	762	2.4	2.8	3.2	4.4
Nonprofits	716	743	876	857	3.9	4.4	5.0	5.0
FFRDC's	110	136	208	263	0.6	0.8	1.2	1.5
Participation in university articles:								
Industry	1,603	1,631	2,310	2,877	2.0	2.1	2.8	3.4
Nonprofits	4,570	4,689	5,831	6,093	5.7	6.0	6.9	7.2
FFRDC's	1,408	1,485	1,811	1,879	1.7	1.9	2.2	2.2
Government	6,372	6,816	7,957	8,228	7.9	8.7	9.5	9.8

Note: One cross-sectoral institutional coauthorship is counted when an article with an author from one sector also lists an author from another sector. For example, in 1973, 1,603 articles listed authors from institutions in both the industry and the university sectors. This represented 13.1 percent of all articles carrying at least one author from industry, and 2.0 percent of articles with at least one university author.

¹ Based on the articles, notes, and reviews in over 2,100 influential journals carried on the 1973 *Science Citation Index Corporate Tapes* of the Institute for Scientific Information.

² U.S. institutions only.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 12 (tabulations prepared for the National Science Foundation, January, 1987)

See figure 5-10.

Science & Engineering Indicators—1987

Appendix table 5-14. United States cross-sector citations: 1973, 1977, 1981, and 1984

Sectors ¹	Year of cited papers			
	1973	1977	1981	1984
	— Relative citation index ² —			
University articles citing:				
Industry	0.38	0.38	0.41	0.36
Nonprofits	1.03	0.93	0.93	0.60
FFRDC's	0.75	0.63	0.73	0.81
Government	0.82	0.84	0.81	0.53
Industry articles citing:				
University	0.65	0.62	0.56	0.38
Nonprofit	0.46	0.43	0.48	0.28
FFRDC's	0.97	0.96	1.03	0.67
Government	0.75	0.77	0.67	0.54
Nonprofit articles citing:				
University	0.95	0.93	0.83	0.62
Industry	0.25	0.26	0.24	0.45
FFRDC's	0.29	0.23	0.30	0.39
Government	1.01	1.06	0.96	0.69
FFRDC articles citing:				
University	0.83	0.80	0.67	0.60
Industry	0.70	0.72	0.73	0.70
Nonprofits	0.40	0.31	0.28	0.26
Government	0.66	0.60	0.61	0.42
Federal government articles citing:				
University	0.83	0.81	0.70	0.49
Industry	0.44	0.42	0.43	0.56
Nonprofits	1.12	1.01	0.97	0.47
FFRDC's	0.66	0.54	0.58	0.62

Note: Based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index Corporate Tapes* of the Institute for Scientific Information.

¹ Articles are assigned to sectors based on the institutional addresses of the articles' authors. Articles with addresses from more than one sector are divided proportionately among the sectors.

² A citation ratio of 1.00 reflects no over- or under-citing of the sector's scientific and technical literature, whereas a higher ratio indicates a greater citation of that sector's articles for that year. For example, literature produced in the nonprofit sector in 1973 received 3 percent more citations from universities than would be expected based on the number of articles published.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 13 (tabulations prepared for the National Science Foundation, January 1987).

Science & Engineering Indicators—1987

Appendix table 5-15. Institutional co-authorship between the industry and university sectors, by field: 1973-84

Fields ¹	1973	1977	1980	1981	1982	1983	1984
University-industry co-authored articles ² as a percent of all industry articles							
All fields	13	15	19	22	24	23	25
Clinical medicine	21	23	30	30	34	33	35
Biomedicine	19	26	32	35	37	35	35
Biology	19	28	35	23	46	42	37
Chemistry	9	10	13	13	17	15	16
Physics	13	15	18	20	21	23	25
Earth and space sciences	28	27	31	34	35	33	36
Engineering and technology	9	10	13	16	17	16	17
Mathematics	28	39	39	43	35	43	42
University-industry co-authored papers ²							
All fields	1,566	1,595	2,017	2,905	3,297	3,386	3584
Clinical medicine	329	331	467	636	768	779	916
Biomedicine	117	148	175	276	305	334	391
Biology	86	113	116	176	246	210	213
Chemistry	185	158	215	269	357	328	327
Physics	246	290	423	508	575	603	650
Earth and space sciences	102	95	119	207	241	222	251
Engineering and technology	463	418	459	746	732	811	757
Mathematics	38	42	43	89	73	100	79
Industry articles							
All fields	12,180	10,544	10,422	13,462	13,705	14,598	14220
Clinical medicine	1,600	1,413	1,533	2,086	2,257	2,394	2608
Biomedicine	618	567	548	782	824	966	1109
Biology	446	407	332	752	533	500	571
Chemistry	1,983	1,539	1,708	1,999	2,124	2,143	2007
Physics	1,911	1,932	2,302	2,559	2,713	2,623	2553
Earth and space sciences	358	348	381	606	691	664	698
Engineering and technology	5,130	4,231	3,507	4,770	4,356	5,075	4483
Mathematics	134	107	111	208	208	235	189

Note: Data for 1973-1980 are based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information. Data for 1981-1984 use over 3,500 journals on the 1981 *Science Citation Index* Corporate Tapes.

¹ See appendix table 5-27 for a description of the subfields included in these fields.

² Articles with authors from both the U.S. industrial sector and the U.S. university sector. Foreign institutions are not divided into sectors.

SOURCE: Computer Horizon, Inc., *Science Indicators Literature Data Base*, Series 12 (tabulations prepared for the National Science Foundation, January 1987).

See figure O-32 in Overview.

Science & Engineering Indicators—1987

Appendix table 5-16. Ways of relating to universities reported by business respondents, by size of company

Ways of relating	All Respondents	Size of company (employees)			
		1-19	20-99	100-499	500 +
		Percent reporting			
Employees attended conferences	45	30	43	59	73
Company recruited graduates	41	19	41	57	81
Company got technical services	41	47	35	35	39
Company provided financial aid for courses	38	17	33	58	75
Informal unpaid interaction	28	25	23	28	45
Company donated funds/equipment	28	18	26	34	50
Internships, co-op education	23	10	17	31	53
Company employed faculty consultants	22	14	19	27	40
Company contributed services to universities	20	16	15	21	38
Other professional interaction	15	11	12	14	29
Universities contributed services to company	12	11	8	8	25
Research contracts	10	6	6	10	27
Research grants consortia	7	4	3	8	19
Universities reimbursed company for services	5	5	3	2	7
Universities held financial interest in company	1	2	¹	1	2
Number of respondents	1,246	458	274	174	192

¹ Less than 0.5 percent.

SOURCE: Donald C. Pelz and Stuart L. Hart, "Business Firm Study: Basic Data on Relations with Universities," Center for Research on Utilization of Knowledge, Institute for Social Research, University of Michigan, May 1, 1986.

Science & Engineering Indicators—1987

Appendix table 5-17. Ways of relating to universities reported by business respondents, by company stage of development

Ways of relating	Stage of development				
	Start-up	Rapid growth	Steady growth	Stable	Declining
	Percent responding				
Employees attended conferences	33	51	49	41	32
Company recruited graduates	25	58	45	34	27
Company got technical services	57	38	37	39	52
Company provided financial aid for courses	12	45	45	34	32
Informal unpaid interaction	28	32	28	27	19
Company donated funds/equipment	11	33	31	27	18
Internships, co-op education	14	30	26	20	15
Company employed faculty consultants	33	29	21	17	19
Company contributed services to universities	22	31	20	16	16
Other professional interaction	24	16	16	13	12
Universities contributed services to company	9	12	13	13	12
Research contracts	14	10	11	8	12
Research grants consortia	7	6	7	8	6
Universities reimbursed company for services	4	7	5	4	3
Universities held financial interest in company	4	2	1	1	3
Number of respondents	81	202	488	368	68

SOURCE: Donald C. Pelz and Stuart L. Hart, "Business Firm Study: Basic Data on Relations with Universities," Center for Research on Utilization of Knowledge, Institute for Social Research, University of Michigan, May 1, 1986.

Science & Engineering Indicators—1987

Appendix table 5-18. Faculty consultants to small business, by field and type of institution

Field ¹	Total	Research universities	Other doctoral universities	Comprehensive colleges and universities	Baccalaureate institutions	Specialized S&T institutions
				Percent ²		
Total	NA	32.4	34.2	55.1	60.0	34.0
Engineering	29.8	23.5	25.0	44.4	NA	17.6
Physical sciences	43.6	41.2	34.1	50.0	62.5	43.5
Environmental sciences	52.1	22.2	30.8	100.0	100.0	0.0
Computer sciences	31.5	21.1	27.8	40.0	50.0	50.0
Mathematics/statistics	52.7	40.0	33.3	66.7	33.3	50.0
Biological sciences	52.2	40.8	51.1	56.0	64.3	NA

Note: Estimated from a national sample (N = 29,395).

Note: NA = Not available.

¹ Field in which faculty member teaches.

² Percent of faculty whose last consulting client was a small business.

SOURCE: F. Darknell and D. Nasatir, "Consulting as a Science Indicator," Final Report to the National Science Foundation under Grant SRS-8307778, May 1, 1987, p. 39.

Science & Engineering Indicators—1987

Appendix table 5-19. Most active university patent classes: 1969-85

Patent class	Total	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Measuring and testing	186	10	10	10	11	11	3	10	9	15	10	14	8	10	11	10	14	20
Surgery	306	9	9	5	10	20	8	24	13	17	14	14	21	17	29	26	36	34
Chemistry, electrical & wave energy ...	148	6	3	4	7	8	6	6	12	8	6	7	7	19	9	13	17	10
Liquid purification or separation	88	1	3	5	4	7	4	3	8	5	9	2	6	3	7	4	6	11
Radiant energy	135	1	4	5	6	7	8	6	15	17	9	4	7	8	9	7	13	9
Chemistry, carbon compounds	252	4	8	9	5	11	8	11	11	15	10	11	19	32	19	15	32	32
Electricity, measuring & testing	90	5	9	4	1	3	5	2	3	3	5	2	3	5	9	7	8	6
Optics, systems & elements	85	3	4	1	3	2	2	4	4	2	6	5	7	7	5	6	8	16
Optics, measuring & testing	77	1	5	9	1	2	3	1	5	3	2	6	8	8	2	9	3	9
Electrical computers & data processing systems	94	1	6	10	2	3	5	5	4	3	8	6	5	4	7	8	12	9
X-ray or gamma ray systems	58	1	1	2	2	6	2	2	8	6	8	2	2	0	8	1	3	4
Chemistry, inorganic	88	3	6	6	4	3	2	11	3	6	15	4	1	8	6	2	4	4
Food or edible material	88	2	0	3	4	4	7	7	4	9	4	4	6	5	7	9	5	8
Drug, bio-affecting & body treating comps. (Patent class 424)	248	4	6	9	5	4	8	13	14	16	15	9	10	19	30	27	40	19
Stock material or misc. articles	58	0	0	2	4	1	4	2	1	4	3	3	3	7	6	8	7	3
Chemistry: mole. biol. & microbiology ..	306	5	4	3	10	7	14	11	14	13	18	12	19	29	38	37	37	35
Chemistry: analytical & immunological testing	150	0	1	1	4	2	2	9	11	11	11	5	17	14	5	12	24	21
Drug, bio-affecting & body treating compositions (Patent class 514)	373	5	3	4	7	6	8	11	19	21	26	18	31	30	40	45	54	45
Organic compounds, part of class 532-570 series. (Patent class 536) ..	73	1	2	2	4	2	2	5	7	3	5	5	2	8	7	6	4	8
Organic compounds, part of class 532-570 series. (Patent class 549) ..	74	0	1	0	0	3	0	4	6	5	6	2	9	11	8	8	7	4
Organic compounds, part of class 532-570 series. (Patent class 568) ..	56	3	0	1	4	1	4	6	7	8	7	0	2	2	2	1	2	6
Prosthesis, parts thereof or aids & accessories	55	2	1	4	7	4	2	1	2	3	1	3	5	4	4	1	1	10

Note: Data are shown for the patent classes that accounted for one percent or more of total academic patenting activity.

SOURCE: U.S. Department of Commerce, Patent and Trademark Office, special tabulations for National Science Foundation.

Field	1960	1965	1970	1975	1980	1981	1982	1983	1984	1985	1986
All fields	13.9	16.8	14.1	15.9	15.9	16.7	17.5	18.5	19.3	21.0	21.1
Science and engineering	18.2	22.0	18.2	21.7	20.8	21.4	22.0	23.4	24.5	26.6	26.7
Physical sciences	13.0	17.4	16.1	22.6	22.9	22.4	23.2	23.5	24.0	25.9	28.8
Physics and astronomy	14.2	19.8	17.3	27.2	24.4	25.2	27.3	29.4	28.0	31.3	34.1
Chemistry	12.5	15.8	15.1	18.8	22.6	21.8	22.7	23.7	27.5	22.7	25.5
Earth sciences	21.8	22.0	20.4	21.0	16.9	17.3	16.7	21.4	21.3	24.5	22.1
Mathematical sciences	23.6	16.5	15.7	23.7	26.7	30.1	32.3	35.0	36.3	37.3	40.8
Mathematics	NA	NA	NA	NA	27.0	31.5	32.4	36.4	38.4	40.7	42.2
Computer sciences	NA	NA	NA	NA	25.7	25.9	32.3	31.5	31.2	29.7	38.3
Engineering	30.1	29.0	26.2	41.1	46.4	49.2	50.1	53.5	53.0	54.8	50.7
Life sciences	21.8	13.6	18.7	19.2	16.5	16.1	15.4	16.4	16.9	19.0	18.2
Biological sciences	17.9	23.8	15.8	14.5	11.8	10.8	11.8	11.7	12.3	14.1	13.3
Agriculture and forestry	35.0	50.9	48.8	37.2	36.3	36.7	29.8	33.8	35.0	35.8	36.5
Social sciences	10.5	13.8	11.9	10.8	10.0	10.5	11.4	10.8	12.5	13.3	13.9
Psychology	5.6	4.5	5.2	5.7	3.9	3.8	3.5	4.3	4.2	4.6	4.6
Other social sciences	15.4	21.7	16.7	14.9	16.7	18.6	20.6	18.9	22.8	23.6	23.6
Total nonscience	6.9	8.5	7.7	8.6	9.8	10.6	11.5	11.8	12.3	13.1	13.1

Science & Engineering Indicat

283

557
513

Appendix table 5-21. U.S. doctoral recipients¹ studying abroad, by field: 1967-83

Year	All S&E fields	Physics	Chemistry	Earth, env., & marine sciences	Engineering	Biosciences	Mathematics	Agricultural sciences	Social sciences	Psychology
Percent of doctoral recipients studying abroad										
1967 ...	2.13	3.49	4.33	1.73	1.11	3.70	1.39	0.71	0.20	0.73
1968 ...	1.73	2.72	3.07	1.36	1.05	3.41	0.71	0.63	0.18	0.43
1969 ...	1.86	3.97	3.19	2.87	0.91	3.39	0.32	0.97	0.33	0.54
1970 ...	1.90	4.18	3.43	2.77	0.75	3.23	1.12	1.00	0.27	0.66
1971 ...	2.39	5.59	5.72	3.16	1.56	3.22	0.74	0.90	0.16	0.64
1972 ...	2.10	4.70	5.14	0.94	1.15	3.42	1.37	1.46	0.18	0.46
1973 ...	1.44	3.42	2.27	1.81	0.63	2.70	1.45	1.13	0.29	0.30
1974 ...	1.43	3.89	3.37	0.79	0.53	2.71	0.53	0.95	0.23	0.50
1975 ...	1.54	2.80	3.03	0.94	1.02	3.10	1.11	0.79	0.36	0.46
1976 ...	1.54	3.14	3.42	1.11	0.91	4.26	0.68	0.75	0.59	0.33
1977 ...	1.33	3.16	2.23	2.75	0.82	3.62	0.58	0.78	0.43	0.25
1978 ...	1.26	2.65	2.32	2.41	0.85	2.55	0.25	0.35	0.16	0.35
1979 ...	1.61	2.99	2.10	1.77	1.15	3.37	1.21	1.05	0.48	0.31
1980 ...	1.42	2.87	2.21	1.30	0.79	2.94	1.02	1.49	0.26	0.28
1981 ...	1.73	4.91	2.41	2.25	0.98	3.51	0.79	1.27	0.37	0.25
1982 ...	1.63	2.30	3.01	2.16	0.70	3.09	0.87	2.24	0.59	0.21
1983 ...	1.46	3.43	2.74	1.95	1.08	2.31	0.66	1.55	0.52	0.26
Number of doctoral recipients studying abroad										
1967 ...	236	39	67	6	24	75	10	3	3	9
1968 ...	214	34	49	5	25	83	6	3	3	6
1969 ...	258	50	56	12	25	92	3	5	6	9
1970 ...	296	60	70	12	22	96	12	6	6	12
1971 ...	397	84	115	16	46	105	8	6	4	13
1972 ...	347	66	93	5	34	110	15	9	5	10
1973 ...	234	45	37	10	17	88	15	7	8	7
1974 ...	212	41	52	4	12	80	5	5	6	7
1975 ...	235	29	46	5	21	96	11	5	10	12
1976 ...	229	31	48	6	17	92	6	4	16	9
1977 ...	191	29	30	16	14	75	5	4	11	7
1978 ...	177	23	30	13	13	80	2	2	4	10
1979 ...	228	26	28	10	18	110	10	6	11	9
1980 ...	201	22	28	7	12	101	8	9	6	8
1981 ...	245	38	32	11	14	120	6	8	8	8
1982 ...	225	17	41	12	10	106	6	15	12	6
1983 ...	214	26	39	10	16	89	3	12	11	8
Number of all U.S. doctoral recipients										
1967 ...	11,063	1,119	1,548	347	2,155	2,026	719	421	1,488	1,240
1968 ...	12,397	1,249	1,594	367	2,378	2,436	841	479	1,647	1,406
1969 ...	13,846	1,258	1,753	418	2,736	2,712	937	516	1,845	1,671
1970 ...	15,545	1,436	2,038	433	2,944	2,975	1,076	602	2,225	1,816
1971 ...	18,589	1,503	2,011	506	2,948	3,264	1,074	663	2,578	2,042
1972 ...	16,530	1,403	1,808	531	2,952	3,216	1,095	618	2,738	2,169
1973 ...	16,246	1,314	1,633	554	2,699	3,258	1,032	617	2,803	2,335
1974 ...	14,840	1,054	1,542	504	2,267	2,957	947	526	2,652	2,391
1975 ...	15,261	1,034	1,519	530	2,134	3,100	923	633	2,781	2,607
1976 ...	14,851	987	1,405	540	1,947	3,160	803	536	2,705	2,768
1977 ...	14,386	919	1,343	581	1,798	3,071	744	514	2,570	2,821
1978 ...	14,056	868	1,293	540	1,586	3,134	666	573	2,448	2,858
1979 ...	14,184	870	1,335	566	1,615	3,262	603	573	2,290	2,895
1980 ...	14,114	766	1,269	538	1,554	3,234	582	627	2,292	2,796
1981 ...	14,174	774	1,329	488	1,471	3,246	525	726	2,191	2,837
1982 ...	13,855	741	1,369	557	1,465	3,399	499	660	2,043	2,965
1983 ...	13,961	760	1,424	513	1,482	3,323	457	685	2,020	3,090

¹ Includes U.S. citizens and foreign citizens with permanent resident status.

Includes medical sciences.

Includes computer science.

SOURCE: National Science Foundation, *Science and Engineering Doctorates: 1960-82* (NSF 83-328); National Research Council, *Summary Report 1983: Doctorate Recipients from United States Universities*, National Academy Press, Washington, D.C., 1983; National Academy of Sciences, *Doctorate Records File*, unpublished data.

Science & Engineering Indicators—1987

Appendix table 5-22. U.S. academic exchange visas issued: 1978-86

Country	1978	1979	1980	1981	1982	1983	1984	1985	1986
Total	67,579	72,131	77,557	84,106	85,714	91,164	97,646	89,448	102,854
United Kingdom	7,219	8,774	9,394	8,416	8,362	8,411	8,836	9,673	12,109
France	3,274	3,194	3,854	4,073	3,962	4,395	4,975	4,695	5,702
West Germany	3,572	3,996	4,420	4,649	5,208	5,823	7,415	7,013	7,914
U.S.S.R.	176	275	234	180	183	160	98	104	328
Poland	905	1,008	1,184	1,374	1,122	863	990	718	737
Other East Europe	1,032	974	1,254	1,239	1,211	1,400	1,659	1,233	1,542
Japan	5,080	6,110	6,190	6,983	6,568	7,403	7,571	5,302	4,944
Taiwan	617	564	819	1,061	1,119	1,309	1,306	915	1,003
Iran	876	266	32	49	87	99	176	158	111
Other countries	44,828	46,970	50,176	56,082	57,892	61,301	64,620	59,637	68,464

SOURCE: Immigrant and Visa Control and Reporting Division, U.S. Department of State, unpublished data

Science & Engineering Indicators—1987

Appendix table 5-23. Internationally co-authored articles, by field: 1973-84

Field ¹	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Internationally co-authored articles as a percent of all institutionally co-authored articles ²												
All fields	12.7	13.3	14.0	14.8	15.1	15.4	16.1	16.3	17.3	17.2	17.8	18.5
Clinical medicine	6.6	6.9	6.8	7.8	7.5	7.7	8.1	8.1	8.8	9.1	9.7	9.9
Biomedicine	13.7	14.2	15.2	15.7	16.3	16.4	16.9	17.1	17.9	18.2	18.8	19.3
Biology	15.5	13.6	15.4	17.0	16.9	17.9	18.6	18.3	19.9	17.7	19.4	21.3
Chemistry	16.3	17.2	17.7	18.1	20.7	20.0	21.5	21.8	22.6	22.6	23.3	24.1
Physics	22.8	23.7	25.4	25.9	27.5	29.4	30.0	30.2	32.6	33.0	32.6	33.8
Earth and space sciences	23.1	22.5	24.6	27.7	27.5	28.7	28.7	30.7	30.2	30.5	32.1	34.1
Engineering and technology	13.2	14.0	15.5	14.0	16.2	17.2	18.2	18.2	19.7	19.9	20.7	20.9
Mathematics	34.3	39.5	39.8	38.6	37.9	38.8	40.0	42.5	42.0	43.9	44.7	47.8
Internationally co-authored articles												
All fields	8,420	9,113	9,737	10,559	11,338	12,317	13,225	14,057	16,558	21,745	23,275	24,799
Clinical medicine	1,881	2,013	1,989	2,314	2,440	2,709	2,837	3,032	3,634	5,084	5,554	5,751
Biomedicine	1,454	1,581	1,775	1,862	2,032	2,156	2,395	2,533	2,828	3,765	3,965	4,181
Biology	723	655	779	853	915	1,007	1,116	1,051	1,371	1,804	2,034	2,308
Chemistry	1,088	1,241	1,286	1,384	1,546	1,600	1,763	1,932	2,253	2,802	2,857	3,073
Physics	1,570	1,757	1,933	2,142	2,320	2,548	2,758	2,960	3,470	4,217	4,334	4,646
Earth and space sciences	647	658	698	830	849	956	1,021	1,108	1,251	1,709	1,827	2,065
Engineering and technology	584	650	720	626	721	806	803	842	1,096	1,416	1,686	1,680
Mathematics	473	558	557	548	515	535	532	600	656	948	1,019	1,096
All institutionally co-authored articles												
All fields	66,105	68,529	69,579	71,220	75,283	79,955	81,894	86,115	95,858	126,509	130,796	133,712
Clinical medicine	28,617	28,974	29,078	29,564	32,643	35,160	35,097	37,250	41,239	55,652	57,513	58,297
Biomedicine	10,648	11,117	11,683	11,845	12,436	13,116	14,144	14,807	15,839	20,642	21,114	21,713
Biology	4,660	4,829	5,073	5,024	5,405	5,620	5,985	5,744	6,875	10,188	10,483	10,818
Chemistry	6,694	7,224	7,264	7,632	7,485	7,996	8,185	8,856	9,986	12,393	12,266	12,759
Physics	6,897	7,410	7,601	8,271	8,433	8,661	9,179	9,792	10,651	12,772	13,289	13,747
Earth and space sciences	2,798	2,920	2,832	2,994	3,085	3,335	3,553	3,615	4,146	5,595	5,699	6,061
Engineering and technology	4,412	4,642	4,647	4,470	4,437	4,689	4,421	4,638	5,562	7,108	8,151	8,021
Mathematics	1,379	1,413	1,401	1,420	1,359	1,378	1,330	1,413	1,561	2,160	2,282	2,295

¹ See appendix table 5-27 for the subfields included in these fields.² 1973-80 data are based on the articles, notes, and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information. The 1981-84 data use over 3,500 journals on the 1981 *Science Citation Index* Corporate Tapes.SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 6 (special tabulations prepared for the National Science Foundation, November 1986)

See figure 5-12.

Science & Engineering Indicators—1987

Appendix table 5-24. International co-authorship, by U.S. sector: 1973, 1980-84

Sector	1973	1980	1981	1982	1983	1984
Percent of articles involving cross-national collaboration						
University and colleges	12.6	15.1	15.7	16.1	17.1	18.2
Nonprofit institutions	5.6	8.0	8.5	9.1	9.9	10.8
FFRDC's	11.9	20.4	20.4	23.3	23.1	24.7
Federal government	6.0	8.9	9.8	10.4	11.5	12.3
Private industry for profit	12.0	15.2	14.8	16.0	15.7	16.3
Number of articles involving cross-national collaboration						
University and colleges	3,898	5,581	7,980	8,484	9,098	9,857
Nonprofit institutions	326	564	829	915	1,024	1,121
FFRDC's	235	464	615	714	757	829
Federal government	530	885	1,331	1,455	1,601	1,733
Private industry for profit	351	550	743	890	944	999
Total articles						
University and colleges	30,998	36,923	50,941	52,825	53,184	54,271
Nonprofit institutions	5,803	7,080	9,736	10,017	10,371	10,380
FFRDC's	1,970	2,274	3,010	3,062	3,284	3,350
Federal government	8,898	9,984	13,593	13,952	13,953	14,134
Private industry for profit	2,930	3,621	5,009	5,577	6,009	6,129

Note: 1973 and 1980 data are based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index Corporate Tapes* of the Institute for Scientific Information. 1981-84 data are based on over 3,500 journals on the 1981 *Science Citation Index Corporate Tapes*.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 12 (tabulations prepared for the National Science Foundation, January 1987)

Science & Engineering Indicators—1987

Appendix table 5-25. Internationally co-authored articles and all institutionally co-authored articles, by country: 1973-84

Country	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Internationally co-authored articles as a percent of all institutionally co-authored articles												
West Germany	35.6	37.3	38.2	40.6	41.3	41.6	43.8	46.2	45.4	46.9	47.9	49.7
United Kingdom	35.3	37.0	37.7	39.6	40.7	40.2	40.4	41.8	41.8	41.6	41.3	42.9
Canada	37.0	45.6	37.3	38.5	38.4	39.4	39.9	40.0	42.7	42.7	40.2	42.0
France	26.7	26.9	29.8	31.4	32.5	33.5	33.9	34.0	34.9	37.3	38.6	39.6
U.S.S.R.	9.6	10.9	13.3	14.2	17.3	16.3	20.1	19.9	18.3	18.5	18.5	18.1
United States	14.0	14.3	15.0	15.9	15.9	15.7	16.6	16.9	17.6	18.2	19.2	20.3
Japan	16.4	16.4	16.1	15.2	15.9	15.5	16.3	16.4	17.3	18.2	18.3	19.3
Internationally co-authored articles												
West Germany	1,283	1,527	1,568	1,741	1,923	2,176	2,244	2,459	3,557	3,767	4,058	4,292
United Kingdom	2,029	2,219	2,364	2,574	2,633	2,784	2,889	3,159	4,492	4,626	4,857	5,150
Canada	1,302	1,369	1,422	1,532	1,599	1,715	1,812	1,819	2,718	2,861	2,862	3,183
France	1,131	1,209	1,460	1,591	1,769	1,837	2,003	2,153	3,062	3,342	3,546	3,761
U.S.S.R.	288	318	380	432	523	528	604	637	836	900	929	869
United States	4,807	5,037	5,254	5,675	5,972	6,248	6,755	7,192	10,268	11,013	11,830	12,743
Japan	472	495	543	555	635	678	767	872	1,334	1,516	1,645	1,878
All institutionally co-authored articles												
West Germany	3,605	4,093	4,108	4,287	4,654	5,228	5,128	5,324	7,842	8,037	8,469	8,628
United Kingdom	5,749	6,002	6,268	6,501	6,473	6,925	7,159	7,553	10,747	11,131	11,762	12,014
Canada	3,521	3,004	3,809	3,976	4,166	4,358	4,543	4,542	6,368	6,697	7,113	7,578
France	4,233	4,492	4,901	5,065	5,445	5,491	5,902	6,341	8,779	8,967	9,175	9,499
U.S.S.R.	3,011	2,926	2,860	3,033	3,031	3,233	3,005	3,199	4,578	4,876	5,015	4,796
United States	34,364	35,338	35,100	35,799	37,618	39,768	40,784	42,508	58,472	60,649	61,688	62,861
Japan	2,881	3,018	3,363	3,657	3,984	4,386	4,696	5,308	7,699	8,336	8,988	9,722

Note: 1973-80 data are based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index Corporate Tapes* of the Institute for Scientific Information. 1981-84 data are based on over 3,500 journals on the 1981 *Science Citation Index Corporate Tapes*.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 6 (tabulations prepared for the National Science Foundation, January 1987)

See figure 5-13.

Science & Engineering Indicators—1987

Appendix table 5-26. U.S. and world scientific and technical articles, by field: 1973-84

Field ¹	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
U.S. articles as a percent of all articles												
All fields	38	38	37	37	37	38	37	37	35	35	35	35
Clinical medicine	43	43	43	43	43	43	43	43	41	41	40	41
Biomedicine	39	38	39	39	39	39	40	40	39	40	39	39
Biology	46	46	45	44	42	42	43	42	37	38	38	37
Chemistry	23	22	22	22	22	21	21	21	20	21	20	21
Physics	33	33	32	31	30	31	30	30	28	27	28	27
Earth and space sciences	47	47	44	46	45	45	45	42	42	42	42	41
Engineering and technology	42	42	41	41	40	39	41	39	38	38	41	40
Mathematics	48	46	44	43	41	40	40	40	36	37	38	37
Number of U.S. articles ²												
All fields	103,777	100,066	97,278	99,970	97,854	99,207	99,377	98,394	134,940	135,953	132,415	131,111
Clinical medicine	32,638	31,691	31,334	32,920	33,516	34,966	33,975	34,612	49,082	49,458	48,055	48,735
Biomedicine	16,115	15,607	15,901	16,271	16,197	16,611	17,649	17,582	22,029	22,892	22,496	22,196
Biology	11,150	10,700	10,400	10,573	9,904	9,663	10,553	9,594	15,070	15,199	14,216	14,166
Chemistry	10,474	9,867	9,222	9,337	8,852	9,266	9,182	9,250	10,946	11,820	11,010	11,137
Physics	11,721	11,945	11,363	11,502	10,995	11,015	10,995	11,415	13,111	13,315	13,021	12,691
Earth and space sciences	5,591	5,371	4,975	5,537	5,197	5,043	5,167	4,832	7,421	7,220	6,862	6,748
Engineering and technology	11,955	11,088	10,431	10,346	10,081	9,694	9,018	8,461	13,282	12,284	13,105	11,976
Mathematics	4,134	3,797	3,652	3,484	3,112	2,949	2,838	2,648	4,000	3,765	3,648	3,462
Number of all articles												
All fields	271,513	265,130	260,908	267,354	263,700	270,128	267,953	269,556	382,327	383,697	373,550	369,930
Clinical medicine	76,209	74,509	73,485	76,699	77,597	81,209	78,827	80,533	119,477	120,926	119,325	119,094
Biomedicine	41,155	40,632	41,244	41,891	41,388	42,968	43,631	44,267	55,787	57,585	57,289	56,223
Biology	24,047	23,414	23,260	23,905	23,757	23,176	24,734	22,838	40,328	39,875	37,788	38,093
Chemistry	45,004	44,529	42,502	42,773	40,734	43,550	43,273	44,448	55,789	56,630	54,186	54,117
Physics	35,854	35,708	35,104	36,902	36,057	35,515	36,700	37,944	46,913	48,677	46,902	46,450
Earth and space sciences	11,977	11,479	11,356	12,011	11,531	11,224	11,596	11,395	17,656	17,241	16,508	16,334
Engineering and technology	28,617	26,600	25,664	25,146	25,003	24,588	22,182	21,459	35,248	32,598	32,073	30,310
Mathematics	8,639	8,259	8,293	8,127	7,573	7,298	7,011	6,673	11,128	10,165	9,478	9,309

Note: 1973-80 data are based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 Science Citation Index Corporate Tapes of the Institute for Scientific Information. 1981-84 data are based on over 3,500 journals on the 1981 Science Citation Index Corporate Tapes.

Note: Detail may not add to totals because of rounding.

¹ See appendix table 5-27 for the subfields included in these fields.

² When an article is written by researchers from more than one country, that article is prorated across the countries involved. For example, if a given article has several authors from France and the United States it is split on the basis of these countries regardless of the number of organizations represented by the authors.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 1 (tabulations prepared for the National Science Foundation, January 1987)

See table O-3 in Overview

Science & Engineering Indicators—1987

Appendix table 5-27. Publications in the fields and subfields of international scientific literature: 1984

Field and subfield	World	United States	Field and subfield	World	United States
Clinical medicine	119,094	48,735	Marine biology & hydrobiology	3,418	1,107
General & internal medicine	17,553	5,802	Botany	9,491	3,347
Allergy	702	291	Ecology	2,771	1,219
Anesthesiology	1,325	450	Agriculture & food science	8,526	3,194
Cancer	5,920	2,727	Dairy animal science	3,315	1,361
Cardiovascular system	4,994	2,357	Miscellaneous biology	2,435	1,140
Dentistry	2,435	1,140	Chemistry	54,117	11,137
Dermatology & venereal diseases	2,853	1,052	Analytical chemistry	5,884	1,528
Endocrinology	4,495	1,688	Organic chemistry	8,155	2,004
Fertility	1,179	535	Inorganic & nuclear chemistry	4,243	745
Gastroenterology	1,910	605	Applied chemistry	2,367	386
Geriatrics	767	491	General chemistry	16,436	2,695
Hematology	2,228	790	Polymers	4,118	893
Immunology	7,918	3,582	Physical chemistry	12,913	2,885
Obstetrics & gynecology	2,319	1,010	Physics	46,450	12,691
Neurology & neurosurgery	10,472	4,522	Chemical physics	5,328	1,923
Ophthalmology	2,363	1,116	Solid state physics	8,298	1,951
Orthopedics	1,149	504	Fluids & plasmas	1,031	538
Arthritis & rheumatism	904	275	Applied physics	10,302	2,761
Otorhinolaryngology	1,392	654	Acoustics	1,130	482
Pathology	2,928	989	Optics	1,940	778
Pediatrics	2,824	1,227	General physics	13,448	2,636
Pharmacology	10,901	3,674	Nuclear & particle physics	3,814	1,299
Pharmacy	4,051	1,110	Miscellaneous physics	1,159	324
Psychiatry	2,289	1,384	Earth & space science	16,334	6,748
Radiology & nuclear medicine	5,109	2,683	Astronomy & astrophysics	3,760	1,605
Respiratory system	1,556	657	Meteorology & atmospheric science	1,545	926
Surgery	5,025	2,667	Geology	2,907	1,135
Tropical medicine	646	154	Earth & planetary science	6,432	2,402
Urology	1,643	811	Geography	2,408	1,295
Nephrology	522	197	Oceanography & limnology	1,635	674
Veterinary medicine	5,477	1,790	Engineering and technology	30,310	11,976
Addictive diseases	443	270	Chemical engineering	3,003	1,312
Hygiene & public health	2,408	1,295	Mechanical engineering	3,036	1,224
Miscellaneous clinical medicine	394	236	Civil engineering	1,926	1,147
Biomedicine	56,223	22,196	Electrical engineering & electronics	7,419	2,970
Physiology	3,910	1,638	Miscellaneous engineering & technology	632	200
Anatomy & morphology	822	251	Industrial engineering	19,043	7,535
Embryology	1,003	419	General engineering	1,046	195
Genetics & heredity	4,573	1,625	Metals & metallurgy	3,855	817
Nutrition & dietetics	1,665	832	Materials science	3,720	1,412
Biochemistry & molecular biology	19,043	7,535	Nuclear technology	2,004	829
Biophysics	975	327	Aerospace technology	1,236	500
Cell biology, cytology & histology	5,115	1,992	Computers	1,860	914
Microbiology	4,640	1,660	Library & information science	388	133
Virology	1,863	788	Operations research & management science	7,938	3,150
Parasitology	1,236	500	Mathematics	9,309	3,462
Biomedical engineering	1,532	630	Probability and statistics	1,593	14,166
Microscopy	388	133	Applied mathematics	2,121	463
Miscellaneous biomedicine	1,521	715	General mathematics	4,706	1,385
General biomedicine	7,938	3,150	Miscellaneous mathematics	3,027	1,610
Biology	38,093	3,990	All fields	369,930	131,111
General biology	1,593	14,166			
General zoology	2,121	463			
Entomology	3,018	402			
Miscellaneous zoology	3,027	1,610			

Note: Based on the articles, notes and reviews in over 3,500 of the influential journals carried on the 1981 *Science Citation Index* Corporate Tapes.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 1 (tabulations prepared for the National Science Foundation, January 1987)

Science & Engineering Indicators—1987

Appendix table 5-28. Total references in U.S. articles and references in U.S. articles to articles from other countries,¹ by field: 1974-84

Field ²	Publication year of citing articles										
	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Percentage of references in U.S. articles to articles from other countries											
All fields	23.0	24.7	26.6	26.9	38.0	27.8	28.4	28.7	28.9	28.9	29.3
Clinical medicine	20.6	23.1	24.1	24.5	25.3	25.4	25.6	25.9	26.0	26.3	26.3
Biomedical research	22.9	25.7	27.2	27.7	29.6	28.5	29.0	29.3	29.4	29.6	29.7
Biology	19.8	22.1	23.0	24.3	24.7	26.4	27.3	27.6	27.1	27.2	27.9
Chemistry	32.1	32.0	37.5	36.4	37.6	36.8	37.9	36.8	38.0	38.3	38.0
Physics	24.7	25.9	27.2	28.3	29.5	30.6	31.3	32.5	33.4	33.3	34.9
Earth and space sciences	17.7	20.5	21.3	22.0	23.1	22.9	24.3	24.4	24.8	23.3	25.8
Engineering and technology	20.3	20.9	23.3	23.2	24.0	24.8	25.0	26.0	26.0	26.1	27.2
Mathematics	16.2	18.4	21.3	24.4	25.6	25.9	27.8	28.4	28.0	29.1	28.5
References in U.S. articles to articles from other countries											
All fields	38,450	79,569	120,676	154,821	182,805	219,434	243,580	283,006	310,817	336,207	321,681
Clinical medicine	9,801	23,552	36,771	49,403	61,336	69,332	77,558	90,439	97,747	105,711	102,682
Biomedical research	10,360	22,010	33,549	42,677	45,010	63,614	71,024	81,833	89,130	95,977	91,719
Biology	1,591	3,826	5,448	7,789	9,374	11,886	13,793	16,935	18,453	20,283	19,561
Chemistry	6,487	10,558	18,828	21,469	26,055	27,064	31,314	34,126	38,677	38,513	36,583
Physics	6,665	11,863	16,286	21,127	24,824	27,461	29,831	36,039	40,197	44,158	41,987
Earth and space sciences	1,961	4,920	5,479	7,154	9,528	12,336	11,746	13,606	15,637	19,800	18,566
Engineering and technology	1,341	2,287	3,351	3,858	4,879	5,892	6,256	7,702	8,583	8,994	8,220
Mathematics	244	554	968	1,344	1,799	1,847	2,057	2,325	2,395	2,771	2,362
Total references in U.S. articles											
All fields	167,397	321,661	454,107	576,508	654,107	788,728	857,782	987,027	1,074,351	1,162,450	1,096,233
Clinical medicine	47,693	102,033	152,429	201,772	242,170	273,094	303,335	349,179	375,595	401,784	390,221
Biomedical research	45,282	85,622	123,445	154,313	151,938	222,833	245,325	279,411	303,674	323,917	308,776
Biology	8,017	17,286	23,639	32,059	37,999	44,971	50,456	61,263	68,027	74,523	70,135
Chemistry	20,221	32,962	50,195	58,986	69,237	73,543	82,646	92,729	101,871	100,596	96,242
Physics	26,981	45,808	59,807	74,754	84,250	89,637	95,264	110,806	120,421	132,547	120,398
Earth and space sciences	11,086	23,989	25,675	32,474	41,171	53,760	48,360	55,851	63,177	85,056	71,933
Engineering and technology	6,609	10,948	14,376	16,632	20,315	23,750	24,999	29,601	33,037	34,517	30,234
Mathematics	1,508	3,012	4,542	5,517	7,027	7,139	7,398	8,189	8,550	9,510	8,295

¹ The number of references found in articles written by scientists and engineers at U.S. institutions, and the number of references in articles written by U.S. authors which were to articles written by S/E's at foreign institutions. References were sought in the articles published in over 2,100 influential journals carried on the Corporate Tapes of the 1973 *Science Citation Index* of the Institute of Scientific Information.

² See appendix table 5-27 for subfields included in the fields.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 2 (Tabulations prepared for the National Science Foundation, January 1987)

See figure O-21 in Overview

Science & Engineering Indicators—1987

Appendix table 5-29. Relative citation ratios¹ for U.S. articles by field: 1973-82

Field	Publication year of cited articles									
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
World citations to U.S.:										
All fields	1.39	1.41	1.41	1.40	1.42	1.41	1.41	1.43	1.38	1.37
Clinical medicine	1.35	1.36	1.36	1.34	1.34	1.35	1.34	1.34	1.33	1.32
Biomedicine	1.42	1.43	1.41	1.42	1.43	1.39	1.38	1.42	1.36	1.34
Biology	1.08	1.12	1.11	1.11	1.16	1.15	1.16	1.17	1.15	1.12
Chemistry	1.64	1.64	1.68	1.65	1.69	1.71	1.72	1.76	1.67	1.63
Physics	1.54	1.53	1.53	1.55	1.56	1.50	1.56	1.54	1.49	1.50
Earth and space sciences	1.37	1.38	1.44	1.36	1.39	1.39	1.45	1.46	1.43	1.49
Engineering and technology	1.28	1.28	1.27	1.23	1.28	1.31	1.29	1.27	1.23	1.18
Mathematics	1.24	1.23	1.22	1.20	1.27	1.32	1.24	1.25	1.25	1.23
Non-U.S. citations to U.S.:										
All fields	1.04	1.03	1.02	1.01	1.00	0.98	0.97	0.96	0.88	0.83
Clinical medicine	1.03	1.02	1.02	1.00	0.99	0.98	0.95	0.93	0.89	0.83
Biomedicine	1.10	1.08	1.07	1.07	1.06	1.00	0.99	1.00	0.92	0.87
Biology	0.71	0.71	0.69	0.68	0.69	0.66	0.66	0.65	0.61	0.53
Chemistry	1.21	1.16	1.18	1.13	1.14	1.14	1.09	1.11	0.98	0.92
Physics	1.21	1.18	1.17	1.17	1.16	1.08	1.12	1.07	1.00	0.97
Earth and space sciences	1.06	1.06	1.10	1.03	1.04	1.05	1.07	1.05	0.97	0.99
Engineering and technology	0.92	0.86	0.84	0.80	0.80	0.83	0.79	0.73	0.67	0.55
Mathematics	0.91	0.90	0.86	0.81	0.85	0.88	0.80	0.77	0.70	0.68
U.S. citations to U.S.:										
All fields	1.85	1.88	1.90	1.90	1.93	1.95	1.96	2.01	1.99	2.02
Clinical medicine	1.70	1.72	1.72	1.72	1.73	1.75	1.74	1.77	1.80	1.84
Biomedicine	1.78	1.82	1.80	1.82	1.83	1.82	1.79	1.85	1.81	1.81
Biology	1.55	1.62	1.63	1.64	1.72	1.75	1.73	1.78	1.80	1.79
Chemistry	2.62	2.75	2.80	2.82	2.91	2.97	3.01	3.10	3.08	3.11
Physics	2.08	2.09	2.14	2.20	2.23	2.19	2.28	2.28	2.27	2.33
Earth and space sciences	1.63	1.64	1.74	1.64	1.68	1.68	1.76	1.79	1.77	1.84
Engineering and technology	1.77	1.79	1.83	1.77	1.84	1.90	1.87	1.92	1.87	1.88
Mathematics	1.58	1.60	1.63	1.68	1.77	1.84	1.79	1.86	1.94	1.94

Note: Based on the articles, notes and reviews in over 2,100 of the influential journals carried on the 1973 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information. For the size of this data base, and the subfields included in the fields, see appendix table 5-27.

¹ The share of citations made to U.S. publications in a field during a particular year, divided by the U.S. share of publications in that year and field. A citation ratio of 1.00 reflects no over- or under-citing of the U.S. scientific and technical literature, whereas a higher ratio indicates a greater influence, impact or utility than would have been expected from the number of U.S. articles for that year. For example, the U.S. chemistry literature for 1973 received 64 percent more citations than expected from the world's chemistry articles.

SOURCE: Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 5 (tabulations prepared for the National Science Foundation, January 1987)

Science & Engineering Indicators—1987

Appendix table 5-30. International collaboration in Deep Sea Drilling Project research areas

	Collaboration Rate ¹
All earth and space sciences, 1982 ²	30
1983 selected research areas: ³	
Deep sea drilling project results: Hydrothermal Mounds of the Galapagos Rift and Other Spreading Centers	41
Basin Evolution and Tectonic History of the Mesozoic Atlantic and Tethys from Deep-Sea Drilling Project data	64
Eocene, Oligocene, and Miocene Stratigraphy and Paleooceanography Evidenced by Foraminiferal Faunas Recovered by the Deep-Sea Drilling Project	58
Seismic Studies of Crustal Structure and Deep-Sea Drilling Project Data from the Atlantic Ocean and Costa Rica Rift	40
Cenozoic Stratigraphy of the Atlantic, Pacific, and Indian Oceans Based on the Calcareous Nannofossils Recovered by the Deep-Sea Drilling Project	58
1985 selected research areas: ³	
Deep-Sea Drilling Evidence of Evolution, Paleoenvironmental and Catastrophic Extinction	39
Oxygen and Carbon Isotopes in Sediments from Deep-Sea Drilling Sediments	40
Late Cenozoic Magnetostratigraphy and Biostratigraphy from Deep-Sea Drilling Sediments	55
Quaternary Biostratigraphy and Climate History from Deep-Sea Drilling Sediments	35
Cenozoic Climates, Stratigraphy and Paleooceanography from Deep-Sea Drilling Project Sites in the Atlantic and Pacific Oceans	33

¹ The percentage of multi-author U.S. articles which have at least one author with a non- U.S. address.

² Based on over 3500 influential journals carried on the 1981 *Science Citation Index* Corporate Tapes of the Institute for Scientific Information.

³ Identified through cocitation clustering. Analysis provided by the Institute for Scientific Information.

SOURCE: Institute for Scientific Information, special tabulations prepared for the National Science Foundation; Computer Horizons, Inc., *Science Indicators Literature Data Base*, Series 6 (tabulations prepared for the National Science Foundation, January 1987)

Science & Engineering Indicators—1987

Appendix table 5-31. Doctoral scientists and engineers leaving research for new activities: 1973/75 to 1983/85

Year	Moved from research to:		
	Development	R&D management	Teaching
	Percent		
Scientists:			
1973-75	2.2	6.8	12.2
1975-77	2.4	7.8	9.7
1977-79	2.4	12.5	11.0
1979-81	1.6	4.3	10.7
1981-83	3.1	5.8	8.7
1983-85	2.9	5.5	7.6
Engineers:			
1973-75	13.5	13.4	7.5
1975-77	13.7	13.3	7.4
1977-79	9.4	25.4	10.3
1979-81	11.7	6.2	9.5
1981-83	11.4	14.9	9.6
1983-85	11.2	8.0	5.5

Note: Data includes those who listed basic or applied research as their primary work activity for the earlier years.

SOURCE: National Academy of Sciences, Doctorate Record File, special tabulation for the National Science Foundation.

Science & Engineering Indicators—1987

Appendix table 6-1. Industry performance and funding of research and development, for selected countries: 1970-87

Year	France	West Germany	Japan	United Kingdom	United States
R&D performed by industry					
Millions national currency					
1970	8,322	8,900	823,265	NA	18,067
1971	9,336	10,521	895,020	NA	18,320
1972	10,570	11,170	1,044,928	831	19,552
1973	11,524	11,761	1,301,927	NA	21,249
1974	13,531	12,733	1,589,053	NA	22,887
1975	15,617	14,469	1,684,847	1,340	24,187
1976	17,992	15,300	1,882,231	NA	26,997
1977	19,999	16,717	2,109,500	NA	29,825
1978	22,500	18,710	2,291,002	2,324	33,304
1979	26,260	23,120	2,664,913	NA	38,226
1980	30,788	NA	3,142,256	NA	44,505
1981	36,805	26,196	3,629,793	3,793	51,810
1982	43,351	NA	4,039,018	NA	57,995
1983	48,098	30,060	4,560,127	4,163	63,405
1984	54,000	NA	5,136,634	NA	71,471
1985	NA	NA	NA	NA	78,181
1986 (Est.)	NA	NA	NA	NA	85,660
1987 (Est.)	NA	NA	NA	NA	90,700
R&D funded by industry					
Millions national currency					
1970	5,465	7,419	792,970	453	10,444
1971	6,094	8,594	896,451	NA	10,822
1972	6,801	8,915	1,056,949	575	11,710
1973	7,578	9,357	1,319,172	NA	13,293
1974	8,770	10,095	1,626,151	NA	14,878
1975	10,235	11,514	1,715,734	823	15,820
1976	12,347	12,220	1,924,345	NA	17,694
1977	13,633	13,596	2,138,892	NA	19,629
1978	NA	14,980	2,330,556	1,552	22,450
1979	19,019	18,540	2,697,945	1,484	26,081
1980	22,269	NA	3,194,604	NA	30,911
1981	25,562	21,860	3,726,055	2,529	35,944
1982	31,157	NA	4,160,607	NA	40,096
1983	35,525	25,144	4,678,482	2,869	43,514
1984	39,200	NA	5,278,564	NA	48,821
1985	43,850	29,841	6,125,416	3,757	52,569
1986 (Est.)	NA	NA	NA	NA	55,699
1987 (Est.)	NA	NA	NA	NA	58,770
Gross domestic expenditures on R&D					
Millions national currency					
1970	14,956	13,903	1,355,505	NA	26,134
1971	16,621	16,527	1,532,372	NA	26,676
1972	18,277	18,212	1,791,879	1,350	28,477
1973	19,789	19,232	2,215,837	NA	30,718
1974	23,031	20,990	2,716,032	NA	32,864
1975	26,203	22,968	2,974,573	2,300	35,213
1976	29,774	24,150	3,320,288	NA	39,018
1977	33,185	25,733	3,651,319	NA	42,783
1978	37,671	28,900	4,045,864	3,680	48,129
1979	44,123	33,457	4,583,630	NA	54,933
1980	51,014	35,903	5,246,247	NA	62,593
1981	62,471	37,703	5,892,356	6,134	71,840
1982	71,836	41,300	6,528,701	NA	79,328
1983	84,671	42,512	7,180,781	6,820	87,204
1984	96,198	44,200	7,893,931	NA	97,639
1985	105,917	49,000	8,890,299	8,150	107,642
1986 (Est.)	117,000	53,400	NA	NA	116,793
1987 (Est.)	NA	NA	NA	NA	124,250

SOURCES: United States: National Science Foundation, *National Patterns of Science and Technology Resources: 1987* (forthcoming); other countries: OECD, Science, Technology, and Industry Indicators Division, unpublished data

See figure 6-1

Science & Engineering Indicators—1987

Appendix table 6-2. Expenditures for industrial R&D, by source of funds: 1960-87

Year	Current dollars			Constant 1982 dollars ¹		
	Total	Company ²	Federal Government ³	Total	Company ²	Federal Government ³
Millions of dollars						
1960	\$10,509	\$4,428	\$6,081	\$33,955	\$14,307	\$19,648
1961	10,908	4,668	6,240	34,917	14,942	19,974
1962	11,464	5,029	6,435	35,892	15,745	20,147
1963	12,630	5,360	7,270	38,981	16,543	22,438
1964	13,512	5,792	7,720	41,032	17,589	23,444
1965	14,185	6,445	7,740	41,992	19,079	22,913
1966	15,548	7,216	8,332	44,474	20,641	23,833
1967	16,385	8,020	8,365	45,590	22,315	23,275
1968	17,429	8,869	8,560	46,194	23,506	22,688
1969	18,308	9,857	8,451	46,023	24,779	21,244
1970	18,067	10,288	7,779	42,986	24,478	18,508
1971	18,320	10,654	7,666	41,280	24,006	17,274
1972	19,552	11,535	8,017	42,056	24,812	17,245
1973	21,249	13,104	8,145	42,893	26,451	16,441
1974	22,887	14,667	8,220	42,415	27,181	15,234
1975	24,187	15,582	8,605	40,781	26,272	14,509
1976	26,997	17,436	9,561	42,805	27,645	15,159
1977	29,825	19,340	10,485	44,330	28,746	15,584
1978	33,304	22,115	11,189	46,115	30,622	15,493
1979	38,226	25,708	12,518	48,652	32,720	15,932
1980	44,505	30,476	14,029	51,919	35,553	16,366
1981	51,810	35,428	16,382	55,140	37,705	17,435
1982	57,995	39,512	18,483	57,995	39,512	18,483
1983	63,403	42,861	20,542	61,047	41,268	19,779
1984	71,471	48,308	23,163	66,343	44,842	21,501
1985 (Prel.)	78,181	51,696	26,485	70,326	46,502	23,824
1986 (Est.)	85,660	54,724	30,936	75,107	47,982	27,125
1987 (Est.)	90,700	57,700	33,000	76,956	48,956	27,999

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

² Includes all sources other than the Federal Government.

³ Data include federally funded R&D centers administered by industry.

Note: Detail may not add to totals because of rounding.

SOURCES: 1960-64: National Science Foundation, *National Patterns of Science and Technology Resources*, 1981 (NSF 81-311), p.21; 1965-84: National Science Foundation, *National Patterns of Science and Technology Resources*, 1984 (NSF 84-311), p.28; 1985-87: National Science Foundation, Division of Science Resources Studies, Industry Studies Group, unpublished data.

See figures 6-2 and O-28 in Overview.

Science & Engineering Indicators—1987

Appendix table 6-3. Expenditures for industrial R&D, by industry: 1960-1985

Industry	1960	1962	1964	1966	1968	1970	1972	1974	1975	1976	1978	1979	1980	1981	1982	1983	1984	1985
Millions of dollars																		
Total	\$10,509	\$11,464	\$13,512	\$15,548	\$17,429	\$18,067	\$19,552	\$22,887	\$24,187	\$26,997	\$33,304	\$38,226	\$44,505	\$51,810	\$57,996	\$63,403	\$71,471	\$78,181
All high-technology manufacturing industries	8,304	9,079	10,680	12,244	13,583	13,685	14,558	16,799	17,914	19,810	23,904	27,233	31,939	38,354	43,813	47,926	54,262	59,666
Chemicals and allied products (SIC 28)	980	1,175	1,284	1,407	1,589	1,773	1,932	2,450	2,727	3,017	3,580	4,038	4,636	5,625	6,659	7,293	8,028	8,667
Machinery (including computers) (SIC 35)	949	914	1,015	1,217	1,483	1,729	2,158	2,985	3,196	3,487	4,283	4,825	5,901	6,818	7,835	8,386	9,667	10,870
Electrical equipment (SIC 36)	2,532	2,639	2,972	3,626	4,083	4,220	4,680	5,011	5,105	5,636	6,507	7,824	9,175	10,329	11,642	13,950	15,694	17,080
Aircraft and missiles (SIC 37, 376)	3,514	4,042	5,078	5,526	5,765	5,219	4,950	5,278	5,713	6,339	7,536	8,041	9,198	11,968	13,658	13,853	16,033	17,619
Professional and scientific instruments (SIC 38)	329	309	331	468	663	744	838	1,075	1,173	1,331	1,998	2,505	3,029	3,614	4,019	4,444	4,840	5,430
All other manufacturing industries	2,037	2,151	2,513	2,807	3,243	3,677	4,287	5,320	5,538	6,342	8,171	9,453	10,751	11,550	12,178	13,288	14,624	15,664
Food, kindred, and tobacco products (SIC 20, 21)	104	121	144	164	184	230	259	298	335	355	472	528	620	719	780	876	1,001	1,042
Textiles and apparel (SIC 22, 23)	38	28	32	51	58	58	61	69	70	82	89	101	115	124	130	144	139	150
Lumber, wood products, and furniture (SIC 24, 25)	10	10	12	12	20	52	64	84	88	107	126	139	148	161	162	169	181	172
Paper and allied products (SIC 26)	56	65	77	117	144	178	189	237	249	313	387	445	495	570	626	747	802	859
Petroleum refining (SIC 29)	296	310	393	371	437	515	468	622	693	767	1,060	1,262	1,552	1,700	2,100	2,229	2,177	2,106
Rubber products (SIC 30)	121	141	158	168	223	276	377	469	467	502	493	577	656	800	850	818	884	1,147
Stone, clay, and glass products (SIC 32)	88	96	109	117	142	167	183	217	233	263	324	356	406	470	500	491	476	486
Primary metals (SIC 33)	177	171	195	232	251	275	277	358	443	506	560	634	728	878	1,000	1,115	715	730
Fabricated metal products (SIC 34)	145	146	148	154	183	207	253	313	324	358	384	455	550	624	568	604	716	624
Motor vehicles (SIC 371)	884	999	1,182	1,344	1,499	1,591	1,954	2,389	2,340	2,778	3,879	4,509	4,955	4,806	4,807	5,337	6,090	7,058
Other manufacturing industries	118	64	63	77	102	128	202	264	296	311	397	447	526	698	655	758	1,443	1,290
Nonmanufacturing industries	168	234	319	497	603	705	707	768	735	845	1,229	1,540	1,815	1,906	2,005	2,189	2,585	2,851

(continued)

Appendix table 6-3. (Continued)

Industry	1960	1962	1964	1966	1968	1970	1972	1974	1975	1976	1978	1979	1980	1981	1982	1983	1984	1985
Millions constant 1982 dollars ¹																		
Total	\$33.955	\$35.892	\$41.032	\$44.474	\$46.194	\$42.986	\$42.056	\$42.415	\$40.781	\$42.805	\$46.115	\$48.652	\$51.919	\$55.140	\$57.996	\$61.047	\$66.343	\$70.326
All high-technology manufacturing industries	26.830	28.425	32.432	35.023	36.001	32.560	31.314	31.132	30.204	31.410	33.099	34.661	37.260	40.819	43.813	46.145	50.369	53.671
Chemicals and allied products (SIC 28)	3.166	3.679	3.899	4.025	4.212	4.218	4.156	4.540	4.598	4.784	4.957	5.139	5.408	5.987	6.659	7.022	7.452	7.796
Machinery (including computers) (SIC 35)	3.066	2.862	3.082	3.481	3.931	4.114	4.642	5.532	5.389	5.529	5.930	6.141	6.884	7.256	7.835	8.074	8.973	9.778
Electrical equipment (SIC 36)	8.181	8.262	9.025	10.372	10.822	10.040	10.067	9.287	8.607	8.936	9.010	9.958	10.703	10.993	11.642	13.432	14.568	15.364
Aircraft and missiles (SIC 372, 376)	11.354	12.655	15.421	15.807	15.280	12.417	10.647	9.781	9.632	10.051	10.435	10.234	10.730	12.737	13.658	13.338	14.883	15.849
Professional and scientific instruments (SIC 38)	1.063	967	1.005	1.339	1.757	1.770	1.803	1.992	1.978	2.110	2.767	3.188	3.534	3.846	4.019	4.279	4.493	4.884
All other manufacturing industries	6.582	6.735	7.631	8.029	8.595	8.749	9.221	9.859	9.337	10.055	11.314	12.031	12.542	12.292	12.178	12.794	13.575	14.090
Food, kindred, and tobacco products (SIC 20, 21)	336	379	437	469	488	547	557	552	565	563	654	672	723	765	780	843	929	937
Textiles and apparel (SIC 22, 23)	123	88	97	146	154	138	131	128	118	130	123	129	134	132	130	139	129	135
Lumber, wood products, and furniture (SIC 24, 25)	32	31	36	34	53	124	138	156	148	170	174	177	173	171	162	163	168	155
Paper and allied products (SIC 26)	181	204	234	335	382	424	407	439	420	496	536	566	577	607	626	719	744	773
Petroleum refining (SIC 29)	956	971	1,193	1,061	1,158	1,225	1,007	1,153	1,168	1,216	1,468	1,606	1,811	1,809	2,100	2,146	2,021	1,894
Rubber products (SIC 30)	391	441	480	481	591	657	811	869	787	796	683	734	765	851	850	788	821	1,032
Stone, clay, and glass products (SIC 32)	284	301	331	335	376	397	394	402	393	417	449	453	474	500	500	473	442	437
Primary metals (SIC 33)	572	535	592	664	665	654	596	663	747	802	775	807	849	934	1,000	1,074	664	657
Fabricated metal products (SIC 34)	468	457	449	441	485	493	544	580	546	568	532	579	642	664	568	582	665	561
Motor vehicles (SIC 371)	2,856	3,128	3,589	3,844	3,973	3,785	4,203	4,427	3,945	4,405	5,371	5,739	5,780	5,115	4,807	5,139	5,653	6,349
Other manufacturing industries	381	200	191	220	270	305	435	489	499	493	550	569	614	743	655	730	1,339	1,160
Nonmanufacturing industries	543	733	969	1,422	1,598	1,677	1,521	1,423	1,239	1,340	1,702	1,960	2,117	2,029	2,005	2,108	2,400	2,565

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.SOURCE: National Science Foundation, *Research and Development in Industry* (annual series).

See figures 6-3 and O-29 in Overview.

Science & Engineering Indicators—1987

Appendix table 6-4. Total employment of R&D-performing companies, by industry: 1960-1985

Industry	1960	1962	1964	1966	1968	1970	1972	1974	1975	1976	1978	1979	1980	1981	1982	1983	1984	1985
	Thousands																	
Total	11,634	11,404	11,561	13,383	14,425	14,443	14,090	14,085	13,455	14,088	14,897	15,549	17,276	17,210	15,596	15,229	15,605	15,229
All high-technology manufacturing industries	4,637	4,807	4,843	5,890	6,480	6,623	6,286	6,403	6,120	6,000	6,417	6,734	7,260	7,419	6,485	6,442	6,791	6,752
Chemicals and allied products (SIC 28)	862	948	954	1,036	1,145	1,065	1,052	1,091	1,088	1,124	1,164	1,224	1,278	1,311	1,281	1,243	1,240	1,263
Machinery (including computers) (SIC 35)	1,249	1,176	1,140	1,351	1,492	1,528	1,483	1,547	1,508	1,470	1,563	1,649	1,847	2,077	1,690	1,495	1,557	1,527
Electrical equipment (SIC 36, 48)	1,362	1,412	1,582	2,135	2,203	2,355	2,319	2,286	2,081	1,984	2,180	2,250	2,286	2,240	1,963	2,173	2,430	2,357
Aircraft and missiles (SIC 372, 376)	884	962	898	1,026	1,241	1,164	965	988	971	927	974	1,039	987	949	940	906	947	987
Professional and scientific instruments (SIC 38)	280	309	269	342	399	511	467	491	472	495	536	572	862	842	611	625	617	618
All other manufacturing industries	5,762	5,735	5,832	6,446	6,726	7,254	7,258	7,110	6,745	7,265	7,566	7,884	8,120	7,762	7,168	6,878	7,097	6,893
Food, kindred, and tobacco products (SIC 20, 21)	737	784	837	774	779	920	987	951	955	930	921	958	1,332	1,298	1,291	1,195	1,346	1,312
Textiles and apparel (SIC 22, 23)	388	376	382	538	633	606	602	600	562	633	608	611	715	628	529	538	531	497
Lumber, wood products, and furniture (SIC 24, 25)	117	99	112	157	201	244	258	254	254	302	335	336	290	296	279	273	288	290
Paper and allied products (SIC 26)	361	402	406	448	473	631	652	592	568	527	523	528	537	522	518	504	507	487
Petroleum refining (SIC 29)	526	506	578	617	627	554	530	469	480	513	526	529	703	716	672	622	618	566
Rubber products (SIC 30)	267	283	309	341	355	381	368	376	343	439	439	445	393	363	360	399	430	406
Stone, clay, and glass products (SIC 32)	na	330	335	363	392	361	348	345	333	404	401	420	434	405	356	342	349	342
Primary metals (SIC 33)	1,036	1,022	1,016	1,124	1,110	1,090	1,049	1,072	1,010	1,056	1,097	1,118	1,068	1,018	880	758	714	673
Fabricated metal products (SIC 34)	407	455	422	476	514	689	687	707	677	601	643	669	570	551	499	449	471	436
Motor vehicles and other transportation equipment (SIC 371, 373-5, 379)	1,146	1,080	1,149	1,264	1,292	1,350	1,308	1,279	1,120	1,283	1,434	1,472	1,381	1,232	1,093	1,111	1,203	1,218
Other manufacturing industries (SIC 27, 31, 39)	777	398	286	344	350	428	469	465	443	577	639	798	697	733	691	687	640	667
Nonmanufacturing industries	1,235	862	886	1,048	1,219	566	546	572	602	824	914	931	1,898	2,028	1,945	1,908	1,841	1,782

SOURCE: National Science Foundation, *Research and Development in Industry* (annual series)

See figure 6-4

Science & Engineering Indicators—1987

Appendix table 6-5. Federal funding of industrial R&D, for selected industries: 1980-85

Industry	1980	1983	1984	1985
Millions of dollars				
Total	\$14,029	\$20,542	\$23,163	\$26,485
Chemicals and allied products (SIC 28)	372	448	232	316
Industrial chemicals (SIC 281-2, 286)	341	440	223	298
Petroleum refining (SIC 29)	151	NA	NA	NA
Primary metals (SIC 33)	135	392	NA	NA
Ferrous metals and products (SIC 331-2, 3398-99)	105	NA	NA	NA
Nonferrous metals and products (SIC 333-6)	30	NA	32	41
Fabricated metal products (SIC 34)	49	62	61	42
Machinery (including computers) (SIC 35) .	647	1,131	1,216	1,536
Electrical equipment (SIC 36)	3,744	5,286	5,956	6,887
Radio and TV receiving equipment (SIC 365)	210	NA	NA	NA
Communication equipment (SIC 366)	1,657	2,572	3,114	3,606
Electronic components (SIC 367)	382	346	452	520
Other electrical equipment (SIC 361-4, 369)	1,495	NA	NA	NA
Motor vehicles and motor vehicle equipment (SIC 371)	655	566	677	978
Aircraft and missiles (SIC 372, 376)	6,628	10,405	12,228	13,421
Professional and scientific instruments (SIC 38)	573	639	660	707
Scientific and mechanical measuring instruments (SIC 381-2)	350	NA	NA	NA
Optical, surgical, photographic, and other instruments (SIC 383-7)	223	NA	NA	NA
Nonmanufacturing industries	779	1,022	1,224	NA
— Millions of constant 1982 ¹ dollars —				
Total	\$16,366	\$19,779	\$21,501	\$23,824
Chemicals and allied products (SIC 28)	434	431	215	284
Industrial chemicals (SIC 281-2, 286)	398	424	207	268
Petroleum refining (SIC 29)	176	NA	NA	NA
Primary metals (SIC 33)	157	377	NA	NA
Ferrous metals and products (SIC 331-2, 3398-99)	122	NA	NA	NA
Nonferrous metals and products (SIC 333-6)	35	NA	30	37
Fabricated metal products (SIC 34)	57	60	57	38
Machinery (including computers) (SIC 35) .	755	1,089	1,129	1,382
Electrical equipment (SIC 36)	4,368	5,090	5,529	6,195
Radio and TV receiving equipment (SIC 365)	245	NA	NA	NA
Communication equipment (SIC 366)	1,933	2,476	2,891	3,244
Electronic components (SIC 367)	446	333	420	468
Other electrical equipment (SIC 361-4, 369)	1,744	NA	NA	NA
Motor vehicles and motor vehicle equipment (SIC 371)	764	545	628	880
Aircraft and missiles (SIC 372, 376)	7,732	10,018	11,351	12,073
Professional and scientific instruments (SIC 38)	668	615	613	636
Scientific and mechanical measuring instruments (SIC 381-2)	408	NA	NA	NA
Optical, surgical, photographic, and other instruments (SIC 383-7)	260	NA	NA	NA
Nonmanufacturing industries	909	984	1,136	NA

¹ GNP implicit price deflator used to convert current dollars to constant dollars.

SOURCE: National Science Foundation, *Research and Development in Industry* (annual series)

Science & Engineering Indicators—1987

Appendix table 6-6. Company funds for research and development by industry: 1970-87

	1970	1972	1974	1976	1978	1980	1981	1982	1983	1984	1985	1986 ¹	1987 ¹
	Millions of dollars												
Total	\$10,283	\$11,535	\$14,667	\$17,436	\$22,115	\$30,476	\$35,428	\$39,512	\$42,861	\$48,308	\$51,696	\$54,724	\$59,500
All high-technology manufacturing industries	6,833	7,468	9,599	11,373	14,383	19,975	24,156	27,529	30,016	33,971	36,802	39,363	42,800
Chemicals and allied products (SIC 28)	1,593	1,741	2,236	2,751	3,250	4,264	5,205	6,226	6,845	7,797	8,352	9,190	9,600
Machinery (including computers) (SIC 35)	1,469	1,758	2,473	2,955	3,901	5,254	6,124	6,977	7,254	8,452	9,334	10,200	10,800
Electrical equipment (SIC 36)	2,008	2,313	2,704	3,081	3,741	5,431	6,409	7,048	8,664	9,738	10,194	10,222	12,500
Aircraft and missiles (SIC 372, 376)	1,213	978	1,278	1,418	1,823	2,570	3,440	3,882	3,448	3,804	4,198	4,751	4,600
Professional and scientific instruments (SIC 38)	550	678	908	1,168	1,668	2,456	2,978	3,396	3,805	4,180	4,724	5,000	5,300
All other manufacturing industries	3,225	3,790	4,763	5,592	7,030	9,464	10,224	10,882	11,678	12,967	NA	NA	NA
Food, kindred, and tobacco products (SIC 20, 21)	222	258	297	NA	NA	NA	636	762	766	1,001	1,042	NA	NA
Textiles and apparel (SIC 22, 23)	NA	61	NA	NA	NA	NA	116	124	125	139	150	NA	NA
Lumber, wood products, and furniture (SIC 24, 25)	52	NA	NA	106	126	148	161	162	169	181	172	NA	NA
Paper and allied products (SIC 26)	NA	NA	NA	NA	NA	495	566	626	674	802	859	NA	NA
Petroleum refining (SIC 29)	493	454	603	715	939	1,401	1,780	1,981	2,030	2,177	2,106	NA	NA
Rubber products (SIC 30)	205	255	NA	NA	NA	NA	598	665	743	884	834	NA	NA
Stone, clay, and glass products (SIC 32)	156	168	NA	NA	NA	363	411	414	451	476	486	NA	NA
Primary metals (SIC 33)	265	264	350	481	497	594	702	721	722	715	730	NA	NA
Fabricated metal products (SIC 34)	201	243	299	322	348	501	545	510	542	654	582	NA	NA
Motor vehicles and other transportation equipment (SIC 371, 373-5, 379)	1,278	1,690	2,141	2,395	3,381	4,388	4,299	4,425	4,931	5,565	6,218	6,600	6,600
Other manufacturing industries	NA	NA	NA	212	266	339	410	492	525	373	NA	NA	NA
Nonmanufacturing industries	225	277	305	471	702	1,037	1,048	1,101	1,167	1,370	1,366	NA	NA

(continued)

Appendix table 6-6. (Continued)

	1970	1972	1974	1976	1978	1980	1981	1982	1983	1984	1985	1986 ¹	1987 ¹
	Millions of constant 1982 dollars ²												
Total	\$24,466	\$24,812	\$27,181	\$27,645	\$32,870	\$35,553	\$37,705	\$39,512	\$41,268	\$44,842	\$46,502	\$47,982	\$50,484
All high-technology manufacturing industries	16,257	16,064	17,789	18,032	21,378	23,303	25,709	27,529	28,900	31,533	33,104	34,514	36,314
Chemicals and allied products (SIC 28)	3,790	3,745	4,144	4,362	4,831	4,974	5,540	6,226	6,591	7,238	7,513	8,058	8,145
Machinery (including computers) (SIC 35)	3,495	3,781	4,583	4,685	5,798	6,129	6,518	6,977	6,984	7,846	8,396	8,943	9,163
Electrical equipment (SIC 36)	4,778	4,975	5,011	4,885	5,560	6,336	6,821	7,048	8,342	9,039	9,170	8,963	10,606
Aircraft and missiles (SIC 372, 376)	2,886	2,104	2,368	2,248	2,710	2,998	3,661	3,882	3,320	3,531	3,776	4,166	3,903
Professional and scientific instruments (SIC 38)	1,309	1,458	1,683	1,852	2,479	2,865	3,169	3,396	3,664	3,880	4,249	4,384	4,497
All other manufacturing industries	7,673	8,152	8,827	8,866	10,449	11,041	10,881	10,882	11,244	12,037	NA	NA	NA
Food, kindred, and tobacco products (SIC 20, 21)	528	555	550	NA	NA	NA	677	762	738	929	937	NA	NA
Textiles and apparel (SIC 22, 23)	NA	131	NA	NA	NA	NA	123	124	120	129	135	NA	NA
Lumber, wood products, and furniture (SIC 24, 25)	124	NA	NA	168	187	173	171	162	163	168	155	NA	NA
Paper and allied products (SIC 26)	NA	NA	NA	NA	NA	577	602	626	649	744	773	NA	NA
Petroleum refining (SIC 29)	1,173	977	1,117	1,134	1,396	1,634	1,894	1,981	1,955	2,021	1,894	NA	NA
Rubber products (SIC 30)	488	549	NA	NA	NA	NA	636	665	715	821	750	NA	NA
Stone, clay, and glass products (SIC 32)	371	361	NA	NA	NA	423	437	414	434	442	437	NA	NA
Primary metals (SIC 33)	631	568	649	763	739	693	747	721	695	664	657	NA	NA
Fabricated metal products (SIC 34)	478	523	554	511	517	584	580	510	522	607	524	NA	NA
Motor vehicles and other transportation equipment (SIC 371, 373-5, 379)	3,041	3,635	3,968	3,797	5,025	5,119	4,575	4,425	4,748	5,166	5,593	5,787	5,600
Other manufacturing industries	NA	NA	NA	336	395	395	436	492	505	346	NA	NA	NA
Nonmanufacturing industries	535	596	565	747	1,043	1,210	1,115	1,101	1,124	1,272	1,229	NA	NA

¹ Estimated² GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

Note: Detail may not add to totals because of rounding.

SOURCE: National Science Foundation, *Research and Development in Industry* (annual series)

Science & Engineering Indicators—1987

**Appendix table 6-7. Share of R&D funding provided by the Federal
Government in selected industries: 1980-85**

Industry	1980	1983	1984	1985
	Percent			
Total	31.5	32.4	32.4	33.9
Chemicals and allied products (SIC 28)	8.0	6.1	2.9	3.6
Petroleum refining (SIC 29)	9.7	NA	NA	NA
Primary metals (SIC 33)	18.5	35.2	NA	NA
Fabricated metal products (SIC 34)	8.9	10.3	8.5	6.7
Machinery (including computers) (SIC 35)	11.0	13.5	12.6	14.1
Electrical equipment (SIC 36)	40.8	37.9	38.0	40.3
Aircraft and missiles (SIC 372, 376)	72.0	75.1	76.3	76.2
Professional and scientific instruments (SIC 38)	18.9	14.4	13.6	13.0
Nonmanufacturing industries	42.9	46.7	47.9	NA

Note: NA - Not Available

SOURCE: See appendix tables 6-5, 6-6.

Science & Engineering Indicators—1987

Appendix table 6-8. U.S. patents granted, by nationality of inventor: 1970-86

	By date of grant								By date of application							
	Inventors from:								Inventors from:							
	All U.S. patents	United States	All other countries	Japan	West Germany	United Kingdom	France	Other countries	All U.S. patents	United States	All other countries	Japan	West Germany	United Kingdom	France	Other countries
1970	64,429	47,077	17,352	2,625	4,435	2,954	1,731	5,607	65,944	45,852	20,092	4,370	5,029	2,726	1,854	6,113
1971	78,317	55,984	22,333	4,029	5,522	3,464	2,214	7,104	66,368	45,591	20,777	4,756	4,997	2,580	2,022	6,422
1972	74,551	51,349	23,202	5,129	5,709	3,149	2,219	6,996	63,372	42,446	20,926	4,588	5,048	2,668	2,113	6,509
1973	74,143	51,500	22,643	4,939	5,587	2,855	2,144	7,118	66,308	42,752	23,556	5,866	5,746	2,782	2,214	6,948
1974	76,278	50,641	25,637	5,892	6,153	3,146	2,569	7,877	66,407	41,853	24,554	6,327	5,856	2,884	2,225	7,262
1975	72,000	46,715	25,285	6,352	6,036	3,043	2,367	7,487	65,846	42,226	23,620	6,074	5,460	2,668	2,151	7,267
1976	70,226	44,280	25,946	6,543	6,180	2,995	2,408	7,820	65,762	41,611	24,151	6,577	5,571	2,618	2,127	7,258
1977	65,269	41,485	23,784	6,217	5,537	2,654	2,108	7,268	65,916	40,801	25,115	7,077	5,965	2,633	2,098	7,342
1978	67,002	42,154	24,848	6,911	5,850	2,722	2,119	7,246	65,524	39,590	25,934	7,473	6,186	2,518	2,271	7,486
1979	48,854	30,079	18,775	5,251	4,527	1,910	1,604	5,483	65,577	38,901	26,676	8,405	6,131	2,489	2,220	7,431
1980	61,819	37,356	24,463	7,124	5,747	2,406	2,088	7,098	66,119	38,688	27,431	9,527	6,162	2,359	2,289	7,094
1981	65,771	39,223	26,548	8,388	6,252	2,475	2,181	7,252	62,906	36,169	26,737	9,918	5,990	2,164	2,052	6,613
1982 ¹	57,888	33,896	23,992	8,149	5,408	2,134	1,972	6,329	64,800	36,700	28,100	11,400	6,000	2,200	2,100	6,400
1983 ¹	56,860	32,871	23,989	8,793	5,423	1,931	1,895	5,947	61,300	34,400	26,900	11,300	5,400	2,100	2,000	6,100
1984 ¹	67,200	38,365	28,835	11,110	6,255	2,271	2,162	7,037	65,900	35,800	30,008	13,100	5,900	2,300	2,200	6,500
1985 ¹	71,661	39,554	32,107	12,746	6,665	2,495	2,400	7,801	69,300	37,000	32,300	15,200	6,300	2,400	2,300	6,200
1986 ¹	70,860	38,124	32,736	13,209	6,803	2,409	2,369	7,946	72,500	39,000	33,500	16,700	6,600	2,400	2,500	5,200

¹ Data by date of application are estimated.

SOURCES: U.S. Department of Commerce, U.S. Patent and Trademark Office, Office of Technology Assessment and Forecast (OTAF), *Special Report: A Profile of U.S. Patent Activity* (1978); OTAF, *Indicators of Patent Output of U.S. Industry, 1963-79* (June, 1980); OTAF, *Indicators of Patent Output of U.S. Industry, 1963-81* (June, 1982); OTAF, *Patenting Trends in the United States, 1963-85* (May, 1986); U.S. Department of Commerce, Patent and Trademark Office, *Patenting Trends in the United States, 1963-86* (June, 1987); U.S. Department of Commerce, Patent and Trademark Office, unpublished data

See figures 6-5, 6-7, and O-22 in Overview

Science & Engineering Indicators—1987

Appendix table 6-9. U.S. patents granted to U.S. inventors, by type of owner: 1970-86

Year	By date of application					By date of grant				
	All patents	U.S. corp.	U.S. Gov't	U.S. individual ¹	Foreign ²	All patents	U.S. corp.	U.S. Gov't	U.S. individual ¹	Foreign ²
1970	45,852	33,104	1,624	10,869	255	47,077	34,978	1,760	10,096	243
1971	45,584	32,627	1,595	11,105	257	55,984	40,925	2,131	12,584	344
1972	42,446	30,578	1,513	10,151	204	51,524	37,960	1,759	11,569	235
1973	42,752	30,573	1,391	10,602	186	51,500	36,853	2,069	12,348	230
1974	41,853	30,167	1,578	9,896	212	50,641	36,119	1,715	12,552	255
1975	42,226	30,338	1,500	10,232	156	46,715	33,429	1,888	11,184	214
1976	41,611	29,128	1,347	10,941	195	44,280	32,174	1,813	10,083	210
1977	40,801	28,500	1,178	10,898	225	41,485	29,566	1,484	10,249	186
1978	39,590	27,704	1,201	10,456	229	41,254	29,421	1,233	10,399	201
1979	38,901	27,285	1,086	10,269	261	30,079	21,145	961	7,804	169
1980	38,688	27,464	1,133	9,798	273	37,356	25,967	1,232	9,940	217
1981	36,169	26,360	1,146	8,414	249	39,223	27,623	1,117	10,241	242
1982 ³	36,700	26,700	1,200	8,500	300	33,896	24,085	1,003	8,539	269
1983 ³	34,400	25,100	1,100	8,000	200	32,871	24,038	1,043	7,562	228
1984 ³	35,800	26,100	1,100	8,300	200	38,365	28,002	1,228	8,887	248
1985 ³	37,000	27,000	1,200	8,600	300	39,554	28,944	1,124	9,243	243
1986 ³	39,000	28,400	1,200	9,100	300	38,124	27,324	1,011	9,461	328

¹ Includes unassigned patents.

² Comprises patents assigned to foreign corporations, governments, and individuals.

³ Data by date of application are estimated.

Note: NA = Not available.

SOURCES: Office of Technology Assessment and Forecast, U.S. Patent and Trademark Office (OTAF), *Special Report: A Profile of U.S. Patent Activity, 1978*, OTAF, *Indicators of Patent Output of U.S. Industry (1963-79)*, June 1980; OTAF, *Indicators of Patent Output of U.S. Industry (1963-81)*, June 1982; and OTAF unpublished data.

See figure 6-6.

Science & Engineering Indicators—1987

Appendix table 6-10. Shares of U.S. patents granted to inventors in various countries, by product field: 1975 and 1986

Product fields	Patents granted to all countries	Country and year of grant							
		United States	Japan	West Germany	United Kingdom	France	Canada	Italy	Other countries
		1975							
		Percent							
All technologies ¹	72,000	64.9	8.8	8.4	4.2	3.3	1.8	1.0	7.6
Food and kindred products	701	70.3	7.7	4.1	5.7	1.7	0.4	0.3	9.7
Textile mill products	475	61.7	9.9	11.8	6.1	3.2	0.8	0.4	6.1
Chemicals, except drugs & medicines ...	10,806	58.5	9.8	11.8	4.6	3.7	1.1	1.6	8.9
Drugs & medicines	1,067	54.8	12.4	10.0	4.7	6.4	1.8	1.8	8.2
Petroleum & natural gas extraction & refining	754	86.3	2.5	1.7	2.8	2.1	2.0	0.1	2.4
Rubber & miscellaneous plastic products	2,931	65.7	10.1	7.8	4.6	3.3	1.8	1.2	5.5
Stone, clay, glass, & concrete products ..	1,375	65.0	8.0	6.8	7.1	3.1	1.4	0.8	7.9
Primary metals	865	53.1	13.1	7.6	4.5	3.1	3.6	0.9	14.1
Fabricated metal products	6,064	71.4	5.4	6.7	3.9	2.7	2.1	0.9	6.9
Machinery, except electrical (excl. Off., computing & accounting machines) ...	15,748	62.6	6.7	9.7	4.3	3.5	2.3	1.2	9.7
Office, computing, & accounting machines	1,465	64.8	12.8	7.8	3.5	2.9	1.0	1.2	5.9
Electrical & electronic machinery, except communication equipment	4,325	64.3	9.6	9.8	4.1	3.1	1.4	1.1	6.5
Communication equipment & electronic components	7,106	66.7	12.7	6.0	4.2	3.3	1.3	0.6	5.2
Motor vehicles and other transportation equipment, except aircraft	3,163	65.8	7.1	9.9	4.9	4.6	1.9	0.9	5.0
Aircraft & parts	705	60.7	9.6	10.2	7.4	5.5	1.8	0.6	4.1
Professional & scientific instruments	8,457	65.9	11.9	7.0	3.4	2.4	1.4	0.7	7.3
		1986							
		Percent							
All technologies ¹	70,860	53.8	18.6	9.6	3.4	3.3	1.9	1.4	8.0
Food and kindred products	454	62.6	11.2	6.4	2.9	3.1	3.1	1.1	9.7
Textile mill products	461	52.1	16.9	12.6	3.7	3.0	1.3	0.7	9.8
Chemicals, except drugs & medicines ...	7,804	53.8	15.2	12.6	3.9	3.8	1.2	1.8	7.7
Drugs & medicines	1,411	48.6	16.2	10.8	6.1	4.7	3.5	2.6	7.6
Petroleum & natural gas extraction & refining	789	80.5	6.3	2.9	1.3	2.2	2.3	0.4	4.2
Rubber & miscellaneous plastic products	2,856	56.2	18.0	10.5	3.3	2.7	1.7	1.2	6.5
Stone, clay, glass & concrete products ..	1,352	53.1	19.5	9.9	3.7	3.3	1.7	1.1	7.7
Primary metals	720	43.1	22.8	9.4	4.4	3.1	3.9	1.0	12.4
Fabricated metal products	5,769	58.9	11.9	9.6	3.3	3.4	2.7	0.9	9.2
Machinery, except electrical (excl. Off., computing & accounting machines) ...	13,766	50.2	15.3	13.5	3.3	3.4	2.1	2.0	10.2
Office, computing, & accounting machines	2,462	46.5	32.6	5.9	2.0	1.7	0.9	1.5	8.9
Electrical & electronic machinery, except communication equipment	4,392	52.5	21.1	9.3	3.4	3.5	1.4	1.6	7.2
Communication equipment & electronic components	8,822	54.2	25.5	5.5	3.5	3.8	1.5	0.7	5.3
Motor vehicles and other transportation equipment, except aircraft	2,809	46.5	23.1	12.8	3.2	3.7	1.8	1.9	7.0
Aircraft & parts	816	40.1	30.4	12.5	4.4	5.0	1.1	1.2	5.3
Professional & scientific instruments	10,048	53.2	23.1	7.7	3.7	2.9	1.6	0.9	6.9

¹ The total number of patents reported under "All technologies" is somewhat greater than the sum of the patents allocated to different product groups, because some patents are not allocated to product groups.

SOURCE: U.S. Department of Commerce, U.S. Patent and Trademark Office, *Patenting Trends in the United States, 1963-1986* (June, 1987), and unpublished data Science & Engineering Indicators—1987

Appendix table 6-11. U.S. patents granted to inventors in various countries, for selected technologies: 1975, 1986

Technology group	Total		United States		Japan		West Germany		France		United Kingdom		Other	
	1975	1986	1975	1986	1975	1986	1975	1986	1975	1986	1975	1986	1975	1986
Patents granted														
All technologies	72,000	70,860	46,715	38,124	6,352	13,209	6,036	6,803	2,367	2,369	3,043	2,409	7,487	7,946
Solar energy	148	432	116	288	6	84	10	18	9	4	3	3	4	35
Jet engines	658	422	437	252	26	37	57	38	31	20	50	23	57	52
Light wave communications	307	497	209	257	47	118	15	40	10	30	19	26	7	26
Light wave & multiplexed light wave communications per se	42	103	31	58	7	18	1	10	2	6	1	6	0	5
Machine tools - metal working	1,121	1,178	724	598	87	200	116	162	27	24	39	37	128	157
Telecommunications	2,532	3,904	1,665	2,043	346	1,028	133	207	91	161	120	167	177	298
Internal combustion engines	1,019	1,213	547	342	170	532	138	170	41	33	53	49	70	87
Steel and iron	593	469	287	173	104	137	54	50	17	19	12	14	119	76
Laser light sources and detectors	79	113	50	57	11	40	5	7	4	3	7	3	2	3
Nuclear energy	409	528	288	296	13	58	32	52	22	62	19	17	35	43
Semiconductor devices & manufacture	1,082	1,586	739	908	141	458	87	81	24	41	38	35	53	63
Light transmitting fiber, waveguide or rod	201	310	140	160	31	64	9	25	4	25	12	17	5	19
General purpose programmable digital computer systems	146	353	113	243	7	68	8	12	2	9	8	7	8	14
Robots	49	214	31	106	10	63	0	16	1	10	0	8	7	11
Genetic engineering	11	116	3	91	3	13	1	4	0	0	0	4	4	4
National shares (percent)														
All technologies			64.88	53.80	8.82	18.64	8.38	9.60	3.29	3.34	4.23	3.40	10.40	11.21
Solar energy			78.38	66.67	4.05	19.44	6.76	4.17	6.08	0.93	2.03	0.69	2.70	8.10
Jet engines			66.41	59.72	3.95	8.77	8.66	9.00	4.71	4.74	7.60	5.45	8.66	12.32
Light wave communications			68.08	51.71	15.31	23.74	4.89	8.05	3.26	6.04	6.19	5.23	2.28	5.23
Light wave & multiplexed light wave communications per se			73.81	56.31	16.67	17.48	2.38	9.71	4.76	5.83	2.38	5.83	0.00	4.85
Machine tools - metal working			64.59	50.76	7.76	16.98	10.35	13.75	2.41	2.04	3.48	3.14	11.42	13.33
Telecommunications			65.76	52.33	13.67	26.33	5.25	5.30	3.59	4.12	4.74	4.28	6.99	7.63
Internal combustion engines			53.68	28.19	16.68	43.86	13.54	14.01	4.02	2.72	5.20	4.04	6.87	7.17
Steel and iron			48.40	36.89	17.54	29.21	9.11	10.66	2.87	4.05	2.02	2.99	20.07	16.20
Laser light sources and detectors			63.29	50.44	13.92	35.40	6.33	6.19	5.06	2.65	8.86	2.65	2.53	2.65
Nuclear energy			70.42	56.06	3.18	10.98	7.82	9.85	5.38	11.74	4.65	3.22	8.56	8.14
Semiconductor devices & manufacture			68.30	57.25	13.03	28.88	8.04	5.11	2.22	2.59	3.51	2.21	4.90	3.97
Light transmitting fiber, waveguide or rod			69.65	51.61	15.42	20.65	4.48	8.06	1.99	8.06	5.97	5.48	2.49	6.13
General purpose programmable digital computer systems			77.40	68.84	4.79	19.26	5.48	3.40	1.37	2.55	5.48	1.98	5.48	3.97
Robots			63.27	49.53	20.41	29.44	0.00	7.48	2.04	4.67	0.00	3.74	14.29	5.14
Genetic engineering			27.27	78.45	27.27	11.21	9.09	3.45	0.00	0.00	0.00	3.45	36.36	3.45

SOURCE: U.S. Department of Commerce, Patent and Trademark Office, unpublished data

Appendix table 6-12. Success rates of patent applications to U.S. Patent and Trademark Office, by applying country: 1975, 1981

Year of application	United States	Japan	Netherlands	United Kingdom	West Germany	Canada	Sweden	France	Switzerland	Italy
	Percent									
1975	65.5	70.9	65.3	58.4	66.1	53.2	65.7	70.6	65.2	60.5
1981	58.0	70.8	61.0	50.4	60.4	51.9	56.9	63.4	61.2	51.2

SOURCE: U.S. Department of Commerce, Patent and Trademark Office, unpublished data

Science & Engineering Indicators—1987

Appendix table 6-13. U.S. employment, by size of firm, 1975-84

	Firm size (number of employees)							Total employment
	Less than 20	20-99	100-499	Total small business	500-999	Greater than 1000	Total large business	
	Thousands							
1975	16,393	16,272	13,713	46,378	4,872	9,315	14,187	60,565
1976	16,821	17,099	14,434	48,354	5,053	9,241	14,294	62,648
1977	17,605	17,815	14,956	50,376	5,157	9,443	14,600	64,976
1978	18,723	19,612	16,327	54,662	5,537	10,090	15,627	70,289
1979	19,406	20,992	17,527	57,925	5,780	10,976	16,756	74,681
1980	19,423	21,168	17,840	58,431	5,689	10,716	16,405	74,836
1981	19,515	21,231	17,977	58,723	5,497	10,630	16,127	74,850
1982	19,898	21,143	17,444	58,485	5,436	10,376	15,812	74,297
1983	20,136	20,806	16,794	57,736	5,186	10,050	15,236	72,972
1984	21,171	22,449	18,348	61,968	5,614	10,413	16,027	77,995
	Average annual growth							
	Percent							
1975-80	3.45	5.40	5.40	4.73	3.15	2.84	0.03	4.32
1980-84	2.18	1.48	0.70	1.48	-0.33	-0.71	-0.58	1.04
1975-84	2.88	3.64	3.29	3.27	1.59	1.25	1.36	2.85

SOURCE: U.S. Bureau of the Census, *Statistical Abstract of the United States: 1987*, Washington, DC (1986), p. 507

Science & Engineering Indicators—1987

Appendix table 6-14. Venture capital¹ resources, commitments and disbursements: 1978-86

Year	Net new private capital committed to venture capital firms ²	Total pool of capital under management	Disbursements excluding SBIC straight debt lending ³ and leveraged buyout financing
	Millions of dollars		
1978	600	3,500	332
1979	300	3,800	665
1980	700	4,500	799
1981	1,300	5,800	1,171
1982	1,800	7,600	1,566
1983	4,500	12,100	2,457
1984	4,200	16,300	2,651
1985	3,300	19,600	2,272
1986	4,500	24,100	2,392

¹ Data describe resources of venture capital firms reporting to Venture Economics, Inc. In 1984-85, the Venture Economics database covered about 600 U.S. venture capital firms.

² Total new private capital less capital withdrawals.

³ Debt financing by licensed Small Business Investment Corporations.

SOURCE: Venture Economics, Inc., special tabulations prepared for the National Science Foundation

See figure 6-8.

Science & Engineering Indicators—1987

Appendix table 6-15. Venture capital investments, by industry: 1984-86

Industry	Early stage investment ¹			Later stage investment ²		
	1984	1985	1986	1984	1985	1986
Millions of dollars						
Total	1,027.6	684.4	928.3	1,389.8	1,344.7	1,292.5
Commercial communications, telephone & data communications	159.0	110.6	127.7	217.0	208.3	242.8
Computers & computer related	387.3	224.0	254.3	680.4	530.7	428.8
Electronic components & other electronics	174.9	110.1	141.1	151.1	214.7	169.2
Biotechnology	20.2	18.8	40.2	42.6	54.9	76.8
Other medical health	132.3	102.1	177.1	108.5	119.2	122.8
Chemicals & materials	14.1	14.5	9.6	5.9	5.3	1.2
Industrial automation	31.4	23.0	12.2	42.7	58.9	35.0
Industrial equipment & machinery	6.4	0.9	6.1	21.5	23.1	14.4
Energy	4.6	6.8	0.3	20.4	15.9	14.1
Consumer	34.7	30.5	82.2	67.0	78.1	116.5
Other	62.7	43.1	77.5	32.7	35.6	70.9
Distribution by industry						
Percent						
Total	100.0	100.0	100.0	100.0	100.0	100.0
Commercial communications, telephone & data communications	15.5	16.2	13.8	15.6	15.5	18.8
Computers & computer related	37.7	32.7	27.4	49.0	39.5	33.2
Electronic components & other electronics	17.0	16.1	15.2	10.9	16.0	13.1
Biotechnology	2.0	2.7	4.3	3.1	4.1	5.9
Other medical health	12.9	14.9	19.1	7.8	8.9	9.5
Chemicals & materials	1.4	2.1	1.0	0.4	0.4	0.1
Industrial automation	3.1	3.4	1.3	3.1	4.4	2.7
Industrial equipment & machinery	0.6	0.1	0.7	1.5	1.7	1.1
Energy	0.4	1.0	0.0	1.5	1.2	1.1
Consumer	3.4	4.5	8.9	4.8	5.8	9.0
Other	6.1	6.3	8.3	2.4	2.6	5.5

¹ Early-stage investment includes capital to develop prototypes, begin production, and initiate marketing. Research and development partnerships to launch new businesses are included.

² Later-stage investment provides capital for the expansion of firms which are already producing and marketing products. It includes bridge financing for firms which are going public, as well as research and development partnerships which fund new product development by established firms.

SOURCE: Venture Economics, Inc., special tabulations prepared for the National Science Foundation

Science & Engineering Indicators—1987

**Appendix table 6-16. Venture-backed initial public offerings by small firms:
1984-86**

Industry	1984	1985	1986
Millions of dollars			
Total	477.6	344.9	1443.8
Commercial communications, telephone & data communications	46.5	66.2	66.3
Computers & computer related	257.9	131.7	376.1
Electronic components & other electronics	61.6	0.0	117.1
Biotechnology	12.7	0.0	269.5
Other medical/health	15.0	27.9	136.4
Industrial automation	9.6	15.2	0.0
Industrial equipment & machinery	8.0	34.2	23.5
Consumer	60.3	54.4	185.5
Other	6.0	15.3	269.5
Distribution by industry			
Percent			
Total	100.0	100.0	100.0
Commercial communications, telephone & data communications	9.7	19.2	4.6
Computers & computer related	54.0	38.2	26.0
Electronic components & other electronics	12.9	0.0	8.1
Biotechnology	2.6	0.0	18.7
Other medical/health	3.1	8.1	9.4
Industrial automation	2.0	4.4	0.0
Industrial equipment & machinery	1.7	9.9	1.6
Consumer	12.6	15.8	12.8
Other	1.3	4.4	18.7

SOURCE: Venture Economics, Inc., special tabulations prepared for the National Science Foundation

Science & Engineering Indicators—1987

Appendix table 6-17. Number of small¹ firms active in selected biotechnology product groups in 1986

All biotechnology	Animal biotechnology	Cell cultures	Catalysts	Bioelectronics	Biotechnology equipment	Enzymes	Genetic engineering	Immunology	Biomass biochemicals	Biomaterials	Proteins	Plant biotechnology	Bioprocessing	Biological testing	Other biotechnology
Number of firms															
252	28	41	9	2	67	22	68	31	32	5	9	16	7	2	1
28	28	4	0	0	3	1	6	4	0	0	0	0	0	0	0
41	4	41	2	0	6	2	3	3	4	0	2	2	1	0	0
9	0	2	9	0	0	4	0	0	1	0	1	0	0	0	0
2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
67	3	6	0	0	67	4	8	1	3	1	1	0	2	0	0
22	1	2	4	0	4	22	7	3	4	0	3	0	2	0	0
68	6	3	0	0	8	7	68	11	3	0	3	1	1	0	1
31	4	3	0	0	1	3	11	31	1	1	3	0	0	0	0
32	0	4	1	0	3	4	3	1	32	2	2	1	2	1	0
5	0	0	0	0	1	0	0	1	2	5	0	0	0	0	0
9	0	2	1	0	1	3	3	3	2	0	9	0	1	0	0
16	0	2	0	0	0	0	1	0	1	0	0	16	0	0	0
7	0	1	0	0	2	2	1	0	2	0	1	0	7	0	0
2	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0
1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1

Note: The table shows the number of firms active in each product group, broken down by the other product groups in which the firms are active. It is thus a symmetric matrix, with the diagonal representing the total number of firms in each product group.

¹ Firms with less than 1,000 employees.

SOURCE: Derived from the CorpTech data base, Corporate Technology Information Services, Inc., Wellesley Hills, MA

Science & Engineering Indicators—1987

**Appendix table 6-18. Small¹ firms active in
selected biotechnology product groups in 1986,
by type of ownership**

Product groups	Total	Publicly held	Privately held
	— Number of firms —		
All biotechnology	252	58	194
Animal biotechnology	28	5	23
Cell cultures	41	8	33
Catalysts	9	2	7
Bioelectronics	2	0	2
Biotechnology equipment ..	67	14	53
Enzymes	22	5	17
Genetic engineering	68	20	48
Immunology	31	12	19
Biomass biochemicals	32	8	24
Biomaterials	5	0	5
Proteins	9	1	8
Plant biotechnology	16	4	12
Bioprocessing	7	1	6
Biological testing	2	1	1
Other biotechnology	1	1	0
	— Percent —		
All biotechnology	100.0	23.0	77.0
Animal biotechnology	100.0	17.9	82.1
Cell cultures	100.0	19.5	80.5
Catalysts	100.0	22.2	77.8
Bioelectronics	100.0	0.0	100.0
Biotechnology equipment ..	100.0	20.9	79.1
Enzymes	100.0	22.7	77.3
Genetic engineering	100.0	29.4	70.6
Immunology	100.0	38.7	61.3
Biomass biochemicals	100.0	25.0	75.0
Biomaterials	100.0	0.0	100.0
Proteins	100.0	11.1	88.9
Plant biotechnology	100.0	25.0	75.0
Bioprocessing	100.0	14.3	85.7
Biological testing	100.0	50.0	50.0
Other biotechnology	100.0	100.0	0.0

¹ Firms with fewer than 1,000 employees.

Note: Because many firms reported activity in more than one field, the sum of the individual fields is greater than the total number of firms reporting biotechnology activity.

SOURCE: Derived from the CorpTech data base, Corporate Technology Information Services, Inc., Wellesley Hills, MA

See figure 6-9.

Science & Engineering Indicators—1987

Appendix table 6-19. Number of small¹ firms active in biotechnology fields, by year of formation

Biotechnology fields	Pre-	Number of firms																				
	1965	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
All biotechnology	32	1	1	3	3	4	3	6	11	8	7	5	11	5	10	18	13	40	25	29	10	7
Animal biotechnology ..	3	0	0	0	0	0	0	0	2	0	2	1	1	0	1	3	3	1	1	7	2	1
Cell cultures	7	0	0	0	2	2	0	1	1	1	1	4	2	0	1	4	2	5	2	5	1	0
Catalysts	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	2	0	1	2	1	0
Bioelectronics	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Biotechnology equipment	9	1	1	2	1	1	2	4	0	5	2	1	7	1	3	3	3	3	6	7	4	1
Enzymes	1	0	0	0	1	0	0	0	0	0	0	0	3	2	1	1	2	5	2	3	1	0
Genetic engineering ...	4	0	0	0	0	0	0	0	4	1	0	0	6	1	4	3	3	16	13	9	1	5
Immunology	3	0	0	0	0	0	1	0	2	1	0	0	1	1	1	3	2	10	1	5	0	0
Biomass biochemicals ..	6	0	0	0	1	2	0	1	0	0	1	1	1	0	5	0	2	5	4	3	0	0
Biomaterials	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0
Proteins	0	0	0	0	0	1	0	0	2	0	0	0	1	3	0	0	0	1	1	0	0	0
Plant biotechnology	1	0	0	1	0	0	0	0	1	1	0	0	0	1	0	2	2	4	2	1	0	0
Bioprocessing	1	0	0	0	0	0	0	0	1	0	0	0	2	0	1	0	0	2	0	0	0	0
Biological testing	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Other biotechnology	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

¹ Firms with less than 1,000 employees.

Note: The table shows the number of firms active in each biotechnology field in 1986, broken down by the year in which they were formed. Because many firms reported activity in more than one field, the sum of the individual fields is generally greater than the total number of firms reporting biotechnology activity.

SOURCE: Derived from the CorpTech data base, Corporate Technology Information Services, Inc., Wellesley Hills, MA

Science & Engineering Indicators—1987

Appendix table 6-20. New products first marketed in 1985, by size of firm

Firm size, millions of dollars in net sales	Number of products per:	
	Millions of dollars of net sales	Millions of dollars of R&D
All firms	0.0076	0.254
Less than 100 ...	0.0892	2.152
100-350	0.0348	1.531
350-1,000	0.0186	0.564
1,000-4,000	0.0072	0.239
4,000 and more .	0.0011	0.037

Note: Data based on sample of 620 firms.

SOURCE: National Science Foundation, Division of Science Resources Studies, Economic Analysis Studies Group, unpublished data

See figure O-30 in Overview.

Science & Engineering Indicators—1987

Appendix table 7-1. U.S. trade in high-technology¹ and other manufacturing product groups: 1970-86

	High technology			Non-high technology			U.S. manufactures		
	Exports	Imports	Balance	Exports	Imports	Balance	Exports	Imports	Balance
Billions of constant 1982 ² dollars									
1970 ³	24.5	10.0	14.5	45.2	54.2	9.0	69.7	64.2	5.5
1971 ³	25.7	11.0	14.6	42.8	61.7	18.9	68.5	72.8	-4.3
1972 ³	25.6	13.6	12.0	46.9	72.5	25.6	72.5	86.0	-13.6
1973 ³	32.1	15.9	16.1	58.1	80.3	22.2	90.2	96.3	-6.1
1974	39.8	18.2	21.7	77.8	92.1	14.3	117.7	110.3	7.4
1975	38.6	16.0	22.6	81.1	76.7	4.4	119.7	92.7	27.0
1976	40.6	20.9	19.7	81.8	89.4	7.6	122.4	110.4	12.1
1977	40.6	22.7	17.8	78.6	99.0	20.4	119.2	121.7	-2.5
1978	48.2	28.1	20.1	82.6	119.8	-37.2	130.9	147.9	-17.0
1979	55.4	29.0	26.4	93.0	122.2	29.2	148.4	151.2	-2.8
1980	63.8	32.7	31.1	117.9	129.2	-11.3	181.8	161.9	19.9
1981	64.3	36.0	28.3	113.3	130.4	-17.1	177.6	166.4	11.2
1982	58.1	34.5	23.6	93.2	123.6	-30.4	151.3	158.1	-6.8
1983	57.9	39.9	18.1	80.2	132.0	-51.7	138.2	171.8	-33.7
1984	60.7	55.1	5.6	86.2	169.0	-82.9	146.9	224.1	-77.3
1985	61.4	58.1	3.3	83.9	183.5	-99.6	145.2	241.5	-96.3
1986	63.3	65.5	-2.3	84.9	204.0	-119.1	148.2	269.5	-121.4
Billions of dollars									
1970 ³	10.3	4.2	6.1	19.0	22.8	3.8	29.3	27.0	2.3
1971 ³	11.4	4.9	6.5	19.0	27.4	-8.4	30.4	32.3	-1.9
1972 ³	11.9	6.3	5.6	21.8	33.7	-11.9	33.7	40.0	-6.3
1973 ³	15.9	7.9	8.0	28.8	39.8	-11.0	44.7	47.7	-3.0
1974	21.5	9.8	11.7	42.0	49.7	-7.7	63.5	59.5	4.0
1975	22.9	9.5	13.4	48.1	45.5	2.6	71.0	55.0	16.0
1976	25.6	13.2	12.4	51.6	56.4	-4.8	77.2	69.6	7.6
1977	27.3	15.3	12.0	52.9	66.6	-13.7	80.2	81.9	-1.7
1978	34.8	20.3	14.5	59.7	86.5	-26.8	94.5	106.8	-12.3
1979	43.5	22.8	20.8	73.1	96.0	-23.0	116.6	118.8	-2.2
1980	54.7	28.0	26.7	101.1	110.8	-9.7	155.8	138.8	17.0
1981	60.4	33.8	26.6	106.5	122.5	-16.1	166.8	156.4	10.5
1982	58.1	34.5	23.6	93.2	123.6	-30.4	151.3	158.1	-6.8
1983	60.2	41.4	18.8	83.3	137.1	-53.7	143.5	178.5	-35.0
1984	65.5	59.5	6.0	92.9	182.3	-89.4	158.4	241.8	-83.3
1985	68.4	64.8	3.6	93.5	204.6	-111.0	162.0	269.4	-107.4
1986	72.5	75.1	-2.6	97.3	233.8	-136.5	169.8	308.9	-139.1

¹ U.S. Department of Commerce DOC-3 definitions.

² Converted to constant dollars using the GNP implicit price deflator.

³ Estimated.

SOURCE: U.S. Department of Commerce, International Trade Administration, *U.S. Trade Performance in 1985 and Outlook* (October, 1986), and U.S. Department of Commerce, unpublished data.

See figure O-26 in Overview.

Science & Engineering Indicators—1987

Appendix table 7-2. U.S. exports as a percentage of shipments, high-technology and other manufactured products: 1978-1985

Product groups	1978	1979	1980	1981	1982	1983	1984	1985
Exports as a percent of shipments								
Percent								
All manufactured products	6.2	6.8	8.4	8.3	7.9	7.0	7.0	6.9
All high-technology products	18.1	19.7	20.5	20.4	18.7	16.5	17.2	17.3
Guided missiles and spacecraft	8.4	6.9	7.5	4.7	8.5	6.6	5.5	4.7
Communications equipment & electronic components	14.0	17.8	15.3	15.1	14.2	11.4	15.9	12.0
Aircraft and parts	35.3	31.6	33.6	35.8	30.3	24.2	25.6	27.9
Office and computing machines	25.1	25.7	28.3	27.7	25.2	21.3	32.1	27.6
Ordnance and accessories	21.5	23.9	20.7	18.9	18.0	22.7	19.5	15.0
Drugs and medicine	12.2	10.4	11.2	11.2	10.2	10.2	9.9	9.2
Industrial inorganic chemicals	16.0	18.1	18.6	19.1	19.3	9.1	20.8	20.0
Professional and scientific instruments	16.3	17.6	18.1	17.9	16.5	15.8	15.3	14.8
Engines, turbines, and parts	19.9	22.9	27.4	26.1	28.5	20.3	26.0	21.4
Plastic materials, synthetics	9.7	13.8	16.2	14.6	14.5	11.9	12.2	12.5
Other manufacturing products	4.5	4.8	6.4	6.2	5.8	5.0	4.9	4.8
Exports								
Millions of dollars								
All manufactured products	94,500	116,600	155,808	166,849	151,264	143,495	158,449	161,974
All high-technology products ¹	34,837	43,523	54,710	60,391	58,111	60,158	65,510	68,426
Guided missiles and spacecraft	635	603	749	557	1,133	994	962	827
Communications equipment & electronic components	6,759	8,327	10,349	11,392	11,803	12,363	14,425	13,472
Aircraft and parts	9,221	11,013	14,558	16,885	14,131	14,637	13,540	17,535
Office and computing machines	4,888	6,374	8,650	9,810	10,148	11,719	14,699	15,421
Ordnance and accessories	539	670	647	676	716	907	845	714
Drugs and medicine	1,492	1,652	1,983	2,220	2,329	2,564	2,672	2,724
Industrial inorganic chemicals	1,999	2,575	2,892	3,111	3,017	3,070	3,543	3,335
Professional and scientific instruments	4,663	5,521	6,490	7,078	7,005	6,867	7,198	7,134
Engines, turbines, and parts	2,362	2,935	3,603	3,831	3,601	3,016	3,234	3,127
Plastic materials, synthetics	2,279	3,853	4,789	4,831	4,228	4,021	4,392	4,137
Other manufacturing products	59,663	73,077	101,098	106,458	93,153	83,337	92,939	93,548
Value of product shipments								
Millions of dollars								
All manufactured products ²	1,522,900	1,727,200	1,852,700	2,017,500	1,908,300	2,045,300	2,274,900	2,341,200
All high-technology products ²	192,678	220,373	266,409	296,639	310,179	364,930	380,109	395,818
Guided missiles and spacecraft	7,535	8,801	9,974	11,795	13,359	15,164	17,354	17,741
Communications equipment & electronic components	48,338	46,820	67,448	75,264	83,373	90,936	108,359	112,417
Aircraft and parts	26,094	34,862	43,322	47,173	46,665	60,407	52,847	62,884
Office and computing machines	19,504	24,767	30,619	35,474	40,206	45,763	55,121	55,847
Ordnance and accessories	2,505	2,809	3,119	3,570	3,970	4,001	4,335	4,747
Drugs and medicine	12,277	15,866	17,772	19,877	22,840	25,017	26,877	29,532
Industrial inorganic chemicals	12,512	14,257	15,570	16,295	15,637	33,807	17,066	16,705
Professional and scientific instruments	28,560	31,359	35,865	39,490	42,404	43,561	47,196	48,318
Engines, turbines, and parts	11,888	12,835	13,156	14,696	12,635	12,449	14,862	14,625
Plastic materials, synthetics	23,467	27,997	29,564	33,004	29,092	33,824	36,092	33,002
Other manufacturing products ²	1,330,222	1,506,827	1,586,291	1,720,861	1,598,121	1,680,370	1,894,791	1,945,382

¹ U.S. Department of Commerce DOC-3 definition

² For Shipments for All Manufacturing Products, total shipments by manufacturers is used. Shipments of Other Manufacturing Products is calculated as the difference between this All Manufacturers total and the total shipments of all high-technology products.

SOURCES: U.S. Department of Commerce, International Trade Administration, *U.S. Trade Performance in 1985 and Outlook* (October 1986); U.S. Department of Commerce, International Trade Administration, Office of Trade and Investment Analysis, unpublished data; Bureau of the Census, *Statistical Abstract of the United States, 1986* (Washington, DC: GPO, 1987); Bureau of the Census, *Annual Survey of Manufactures, Value of Product Shipments (M85)(AS)-2*, January, 1987 and previous editions.

See figure O-27 in Overview

Science & Engineering Indicators—1987

Appendix table 7-3. U.S. direct investment position abroad in manufacturing in selected nations and product groups: 1966-86

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Millions of constant 1982 dollars ¹																					
Total manufacturing	\$59,325	\$63,447	\$66,684	\$71,222	\$73,873	\$77,420	\$82,437	\$89,564	\$94,833	\$94,227	\$96,973	\$92,180	\$96,468	\$100,089	\$104,014	\$98,325	\$83,452	\$79,826	\$79,593	\$85,280	\$93,685
Total major countries	38,733	40,256	41,540	44,208	45,527	47,596	50,619	54,804	56,677	55,598	57,227	54,321	56,198	57,649	53,710	55,033	45,994	45,527	44,892	49,386	54,724
Canada	19,156	19,641	19,971	21,126	21,344	21,415	22,566	23,728	24,926	24,770	25,313	21,990	21,789	22,136	22,022	21,086	18,825	18,495	19,453	19,591	20,756
France	3,324	3,506	3,453	3,680	4,311	4,748	5,251	5,941	6,353	6,481	6,337	6,257	6,475	6,527	6,902	5,874	4,318	3,868	3,704	4,612	5,749
West Germany	5,000	5,442	5,696	6,488	6,365	7,001	7,823	8,966	8,921	8,983	10,633	10,797	11,559	10,914	11,266	10,695	9,089	8,880	8,213	9,607	11,363
United Kingdom	10,206	10,437	11,023	11,292	11,680	12,228	12,431	13,345	13,660	12,738	12,263	12,351	13,131	14,541	10,054	13,935	10,704	10,514	9,744	11,457	12,252
Japan	1,047	1,230	1,397	1,621	1,827	2,204	2,549	2,824	2,817	2,625	2,681	2,925	3,244	3,532	3,467	3,444	3,058	3,769	3,778	4,119	4,634
Other countries	20,592	23,191	25,144	27,014	28,346	29,824	31,818	34,760	38,156	38,629	39,746	37,860	40,270	42,440	50,304	43,292	37,458	34,299	34,701	35,894	38,961
Total chemical products	10,984	12,635	13,432	13,924	13,954	14,689	15,601	16,986	18,851	18,727	19,317	17,634	19,370	21,100	22,035	21,473	18,274	18,080	17,798	18,268	20,134
Total major countries	5,947	6,322	6,494	6,604	6,652	7,174	7,554	8,359	8,953	8,855	9,063	8,077	8,999	10,130	10,254	9,951	8,636	9,026	8,748	9,214	10,190
Canada	3,026	3,189	3,239	3,260	3,141	3,274	3,405	3,567	3,797	3,824	3,904	3,343	3,568	3,775	3,969	3,968	4,178	4,377	4,438	4,347	4,474
France	469	598	599	669	711	744	839	914	1,006	998	1,012	1,029	1,045	1,170	1,224	1,109	797	717	638	712	1,006
West Germany	512	556	633	651	702	840	914	1,167	1,281	1,298	1,451	1,280	1,609	1,774	1,750	1,738	1,092	1,095	891	1,014	1,248
United Kingdom	1,691	1,692	1,675	1,619	1,670	1,845	1,871	2,103	2,263	2,128	2,104	1,735	2,023	2,558	2,495	2,330	1,791	1,731	1,669	1,959	2,033
Japan	249	287	347	405	428	471	525	608	606	607	593	691	753	853	817	816	770	1,105	1,123	1,181	1,429
Other countries	5,037	6,313	6,939	7,320	7,302	7,515	8,047	8,627	9,988	9,872	10,254	9,557	10,371	10,970	11,780	11,522	9,638	9,064	9,050	9,054	9,943
Total machinery	14,396	15,178	15,865	17,627	18,658	20,122	21,716	23,841	25,930	26,294	27,098	16,681	18,010	26,631	27,264	25,812	21,132	20,818	21,328	24,726	26,819
Total major countries	10,255	10,746	NA	NA	NA	13,659	14,668	15,662	16,481	16,439	16,567	11,785	12,681	16,331	16,616	15,314	11,925	12,012	12,325	14,518	15,765
Canada	3,847	3,962	3,997	4,382	4,218	4,261	4,541	4,693	4,970	5,129	5,147	2,307	2,390	3,686	3,688	3,852	3,302	3,535	3,787	3,645	3,684
France	1,267	1,233	1,209	1,264	1,475	1,676	1,794	2,041	2,213	2,386	2,228	2,347	2,541	2,809	3,045	2,560	1,716	1,451	1,447	2,178	2,687
West Germany	1,505	1,622	2,364	2,278	2,315	2,641	2,986	3,397	3,612	3,542	3,862	2,933	3,223	4,079	3,955	3,403	3,009	3,054	2,945	3,762	4,282
United Kingdom	3,001	3,189	3,173	3,550	3,783	3,930	3,986	4,053	4,249	4,055	3,963	2,933	3,038	4,172	4,362	3,996	2,552	2,449	2,524	3,143	3,279
Japan	635	740	NA	NA	NA	1,151	1,362	1,478	1,436	1,327	1,367	1,266	1,489	1,585	1,567	1,504	1,346	1,523	1,622	1,790	1,832
Other countries	4,142	4,432	NA	NA	NA	6,462	7,049	8,179	9,450	9,855	10,531	4,896	5,330	10,300	10,649	10,498	9,207	8,806	9,004	10,208	11,054
Millions of dollars																					
Total manufacturing	\$20,740	\$22,803	\$25,160	\$28,332	\$31,049	\$34,359	\$38,325	\$44,370	\$51,172	\$55,886	\$61,161	\$62,019	\$69,669	\$78,640	\$89,161	\$92,386	\$83,452	\$82,907	\$85,865	\$95,104	\$107,241
Total major countries	13,541	14,468	15,673	17,586	19,135	21,123	23,533	27,150	30,583	32,975	36,093	36,547	40,586	45,295	46,040	51,709	45,994	47,284	48,430	55,075	62,642
Canada	6,697	7,059	7,535	8,404	8,971	9,504	10,491	11,755	13,450	14,691	15,965	14,795	15,736	17,392	18,877	19,812	18,825	19,209	20,986	21,849	23,749
France	1,162	1,260	1,303	1,464	1,812	2,107	2,441	2,943	3,428	3,844	3,997	4,210	4,676	5,128	5,916	5,519	4,318	4,017	3,906	5,143	6,581
West Germany	1,748	1,956	2,149	2,581	2,675	3,107	3,637	4,442	4,814	5,328	6,706	7,264	8,348	8,575	9,657	10,049	9,089	9,223	8,860	10,714	13,007
United Kingdom	3,568	3,751	4,159	4,492	4,909	5,427	5,779	6,611	7,371	7,555	7,734	8,310	9,483	11,425	8,618	13,093	10,704	10,920	10,512	12,777	13,990
Japan	366	442	527	645	768	978	1,185	1,399	1,520	1,557	1,691	1,968	2,343	2,775	2,972	3,236	3,058	3,915	4,076	4,593	5,305
Other countries	7,199	8,335	9,487	10,746	11,914	13,236	14,792	17,220	20,589	22,911	25,068	25,472	29,083	33,345	43,121	40,677	37,458	35,623	37,435	40,029	44,599
Total chemical products	3,840	4,541	5,068	5,539	5,895	6,519	7,253	8,415	10,172	11,107	12,183	11,864	13,989	16,578	18,888	20,176	18,274	18,788	19,200	20,372	23,047
Total major countries	2,079	2,272	2,450	2,627	2,796	3,184	3,512	4,141	4,831	5,252	5,716	5,434	6,499	7,959	8,790	9,350	8,636	9,374	9,437	10,275	11,665
Canada	1,058	1,146	1,222	1,297	1,320	1,453	1,583	1,767	2,049	2,268	2,462	2,249	2,577	2,966	3,402	3,719	4,178	4,586	4,777	4,848	5,121
France	164	215	226	266	299	330	390	453	543	592	638	692	755	919	1,049	1,042	797	745	688	794	1,152
West Germany	179	200	239	259	295	373	425	578	691	770	915	861	1,162	1,334	1,500	1,633	1,092	1,137	961	1,131	1,429
United Kingdom	591	608	632	644	702	819	870	1,042	1,221	1,262	1,327	1,167	1,461	2,010	2,139	2,189	1,791	1,798	1,800	2,185	2,327
Japan	87	103	131	161	180	209	244	301	327	360	374	465	544	670	700	767	778	1,148	1,211	1,317	1,636
Other countries	1,761	2,269	2,618	2,912	3,069	3,335	3,741	4,274	5,341	5,855	6,467	6,430	7,490	8,619	10,098	10,826	9,638	9,414	9,763	10,097	11,382
Total machinery	5,033	5,455	5,986	7,012	7,842	8,930	10,096	11,811	13,992	15,595	17,091	11,223	13,007	20,924	23,371	24,253	21,132	21,622	23,009	27,574	30,700
Total major countries	3,585	3,862	NA	NA	NA	6,062	6,819	7,759	8,893	9,750	10,449	7,929	9,158	12,831	14,243	14,389	11,925	12,476	13,296	16,190	18,046
Canada	1,345	1,424	1,508	1,743	1,773	1,891	2,111	2,325	2,682	3,042	3,246	1,552	1,726	2,896	3,161	3,619	3,302	3,671	4,085	4,065	4,217
France	443	443	456	503	620	744	834	1,011	1,194	1,415	1,405	1,579	1,835	2,207	2,610	2,405	1,716	1,507	1,561	2,429	3,076
West Germany	526	583	892	906	973	1,172	1,388	1,683	1,949	2,101	2,436	1,973	2,328	3,205	3,390	3,197	3,009	3,172	3,177	4,195	4,902
United Kingdom	1,049	1,146	1,197	1,412	1,590	1,744	1,853	2,008	2,293	2,405	2,500	1,973	2,194	3,278	3,739	3,755	2,552	2,544	2,723	3,505	3,754
Japan	222	266	NA	NA	NA	511	633	732	775	787	862	852	1,075	1,245	1,343	1,413	1,346	1,582	1,750	1,996	2,097
Other countries	1,448	1,593	NA	NA	NA	2,868	3,277	4,052	5,099	5,845	6,642	3,294	3,849	8,093	9,128	8,864	9,207	9,146	9,713	11,383	12,654

Note: Certain data are withheld by the U.S. Commerce Department to avoid disclosure of data for individual companies.

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.SOURCES: U.S. Department of Commerce, Bureau of Economic Analysis, *Selected Data on U.S. Direct Investment Abroad, 1966-78 (1980)*; U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (annual, August issues); U.S. Department of Commerce, *Statistics*.

See figures 7-1, 7-2.

Science & Engineering Indicators—1987

Appendix table 7-4. Operations of overseas affiliates of U.S. corporations, selected high-technology manufacturing and service industries: 1984

Industry of affiliates	Affiliate sales	Affiliate profits	Exports shipped to affiliates	Net affiliate sales ¹	Total U.S. exports ²	Total foreign operations: exports + net affiliate sales	Total Shipments ¹	Total revenues: domestic shipments + net affiliate sales
Millions of dollars								
All manufacturing industries . . .	369,333	16,387	47,260	322,073	158,449	480,522	2,253,847	2,575,920
High technology manufacturing industries ¹ .	117,009	7,743	15,968	101,041	50,163	151,204	378,135	479,176
Radio, television and communications equipment	8,814	376	1,174	7,640	7,762	15,402	67,012	74,652
Electronic components & accessories	13,600	967	3,977	9,623	6,663	16,286	47,983	57,606
Office & computing machines	30,914	2,870	4,476	26,438	14,699	41,137	59,715	86,153
Drugs & medicines	14,477	1,200	1,238	13,239	2,672	15,911	28,967	42,206
Industrial chemicals & synthetics	34,218	1,717	2,504	31,714	7,935	39,649	99,518	131,232
Instruments & related products	12,759	617	2,317	10,442	7,198	17,640	59,447	69,889
Engines & turbines	2,227	(4)	282	1,945	3,234	5,179	15,494	17,439
Other manufacturing industries	252,324	8,644	31,292	221,032	108,286	329,318	1,875,712	2,096,744
All service industries	19,888	1,350	161	19,727	70,950	90,677	3,457,300	3,477,027
Computer & data processing services	1,105	28	47	1,058	3,500	4,558	40,542	41,600
R&D and testing laboratories	282	14	NA	NA	NA	NA	NA	NA
Engineering, architectural, and surveying services	3,029	155	3	3,026	1,200	4,226	40,200	43,226
Other service industries	15,472	1,153	NA	NA	NA	NA	NA	NA
Percent								
All manufacturing industries . . .	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100
High technology manufacturing industries ¹ .	31.7	47.3	33.8	31.4	31.7	31.5	16.8	19
Radio, television and communications equipment	2.4	2.3	2.5	2.4	4.9	3.2	3.0	3
Electronic components & accessories	3.7	5.9	8.4	3.0	4.2	3.4	2.1	2
Office & computing machines	8.4	17.5	9.5	8.2	9.3	8.6	2.6	3
Drugs & medicines	3.9	7.3	2.6	4.1	1.7	3.3	1.3	2
Industrial chemicals & synthetics	9.3	10.5	5.3	9.8	5.0	8.3	4.4	5
Instruments & related products	3.5	3.8	4.9	3.2	4.5	3.7	2.6	3
Engines & turbines	0.6	0.0	0.6	0.6	2.0	1.1	0.7	1
Other manufacturing industries	68.3	52.7	66.2	68.6	68.3	68.5	83.2	81

(continued)

Appendix table 7-4. (Continued)

Industry of affiliates	Net affiliate sales as a percent of foreign operations	Net affiliate sales as a percent of total revenues	Foreign operations as a percent of total revenues
		Percent	
All manufacturing industries . . .	67.0	12.5	18.7
High technology			
manufacturing industries ¹ . . .	66.8	21.1	31.6
Radio, television and communications equipment	49.6	10.2	20.6
Electronic components & accessories	59.1	16.7	28.3
Office & computing machines	64.3	30.7	47.7
Drugs & medicines	83.2	31.4	37.7
Industrial chemicals & synthetics	80.0	24.2	30.2
Instruments & related products	59.2	14.9	25.2
Engines & turbines	37.6	11.2	29.7
Other manufacturing industries	67.1	10.5	15.7
All service industries	21.8	0.6	2.6
Computer & data processing services	23.2	2.5	11.0
R&D and testing laboratories	NA	NA	NA
Engineering, architectural, and surveying services	71.6	7.0	9.8
Other service industries	NA	NA	NA

¹ Affiliate sales less U.S. exports shipped to affiliates.

² Manufacturing exports are broken down by SIC product groups. Radio, television, and communications equipment and Electronic components & accessories are estimated by dividing U.S. exports of communications equipment & electronic components according to the distribution of affiliate sales in the two industries. Service exports are the midrange of the OTA estimates.

³ Shipments of services are the OTA estimates for Domestic Industry.

SOURCES: U.S. Department of Commerce, Bureau of Economic Analysis, *U.S. Direct Investment Abroad: Operations of U.S. Parent Companies and their Foreign Affiliates*, 1986), Tables 2, 17; U.S. Department of Commerce, International Trade Administration, *United States Trade Performance in 1985 and Outlook* (October, 1986); U.S. Department of Commerce, Bureau of the Census, *Annual Survey of Manufactures: Statistics for Industry Groups and Industries*, MB4(AS)-1 (July, 1986); U.S. Congress, Office of Technology Assessment, *Trade in Services: Exports and Foreign Revenues—Special Report*, OTA-ITE-316 (September, 1986)

See figures 7-3, 7-4.

Science & Engineering Indicators—1987

Appendix table 7-5. Foreign direct investment position in the United States in manufacturing, by nationality of parent company, in selected industries: 1979-86

	1979	1980	1981	1982	1983	1984	1985	1986
Millions of constant 1982 dollars ¹								
Total manufacturing	\$26,570	\$38,510	\$43,139	\$44,065	\$45,894	\$48,085	\$53,597	\$59,673
Total major countries	18,855	16,681	40,103	40,057	41,646	44,012	48,930	53,811
Canada	4,601	11,752	3,593	3,500	3,190	3,820	4,144	4,725
France	1,359	NA	5,177	4,974	5,283	4,983	5,143	5,251
West Germany	3,106	NA	4,469	4,239	4,320	4,074	5,411	6,958
Netherlands	4,458	NA	9,598	9,901	10,805	11,600	12,010	12,900
United Kingdom	4,411	NA	8,091	8,504	8,878	9,022	10,513	13,151
Japan	919	4,929	1,406	1,624	1,545	2,283	2,463	2,645
Switzerland	NA	NA	3,489	3,584	4,010	4,431	6,190	6,795
Netherlands Antilles	NA	NA	4,282	3,731	3,614	3,798	3,057	1,384
Other countries	7,715	21,829	3,035	4,008	4,247	4,073	4,668	5,862
Total chemical products	9,012	12,178	14,582	14,377	15,180	15,438	16,943	20,158
Total major countries	5,460	NA	8,858	13,727	14,433	14,577	16,264	19,425
Canada	129	NA	102	125	96	102	130	235
France	313	NA	NA	2,915	2,860	2,691	2,694	2,710
West Germany	2,089	NA	2,090	1,972	2,109	2,105	3,352	4,184
Netherlands	1,123	NA	2,211	2,237	2,814	3,095	3,203	4,018
United Kingdom	1,569	NA	2,900	3,079	3,082	3,103	3,270	4,748
Japan	238	NA	265	252	272	234	241	253
Switzerland	NA	NA	1,290	1,359	1,631	1,844	1,936	1,868
Netherlands Antilles	NA	NA	NA	1,788	1,568	1,403	1,438	1,408
Other countries	3,552	NA	5,724	650	747	860	679	733
Total machinery	4,255	8,160	8,830	8,595	8,288	8,987	8,306	8,797
Total major countries	3,489	NA	6,656	6,518	6,263	6,720	6,879	7,847
Canada	1,493	NA	1,253	988	978	1,114	1,088	1,404
France	69	NA	0	75	106	149	192	189
West Germany	263	NA	1,207	1,254	1,039	900	928	1,519
Netherlands	985	NA	1,659	1,847	1,809	1,804	1,617	1,726
United Kingdom	476	NA	1,497	1,338	1,363	1,615	1,777	1,534
Japan	202	NA	442	423	449	583	643	765
Switzerland	NA	NA	598	593	519	554	631	711
Netherlands Antilles	NA	NA	NA	NA	NA	NA	NA	NA
Other countries	766	NA	2,174	2,077	2,025	2,268	1,428	950

Note: Certain data are withheld by the U.S. Commerce Department to avoid disclosure of data for individual companies.

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

SOURCES: U.S. Department of Commerce, Bureau of Economic Analysis, *Selected Data on U.S. Direct Investment Abroad, 1966-78 (1980)*; U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (February 1981), pp.50-51; U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (annual, August issues)

See figure 7-5.

Science & Engineering Indicators—1987

Appendix table 7-6. Foreign direct investment position in the U.S., high-technology industries: 1980-86

Industries	1980	1981	1982	1983	1984	1985	1986
	Millions of 1982 dollars ¹						
All manufacturing industries	38,510	43,139	44,065	45,894	48,018	53,429	59,673
High-technology industries ²	13,419	16,469	16,830	17,850	18,208	19,463	22,756
Radio, television, and communications equipment	1,288	1,668	1,744	1,736	1,838	1,766	2,850
Electronic components & accessories	1,776	2,029	2,199	2,269	2,541	1,948	819
Office and computing machines	517	576	685	730	1,057	919	864
Drugs and medicine	1,777	1,681	1,796	2,053	2,127	2,177	2,922
Industrial chemicals and synthetics	7,290	9,811	9,607	10,112	9,855	11,517	13,378
Instruments and related products	685	624	705	855	673	941	1,546
Engines and turbines	87	82	94	95	117	195	378
Other manufacturing industries	25,091	26,670	27,235	28,044	29,810	33,966	36,917
All service industries	1,270	1,415	1,899	2,005	2,298	2,639	5,250
Computer & data processing services	62	64	77	126	224	230	301
R&D and testing laboratories	64	61	63	72	70	74	83
Engineering, architectural & surveying services	150	152	155	117	157	179	722
Other service industries	994	1,139	1,604	1,690	1,846	2,155	4,145
	Millions of dollars						
All manufacturing industries	33,011	40,533	44,065	47,665	51,802	59,584	68,057
High-technology industries ²	11,503	15,474	16,830	18,539	19,643	21,705	25,953
Radio, television, and communications equipment	1,104	1,567	1,744	1,803	1,983	1,969	3,250
Electronic components & accessories	1,522	1,906	2,199	2,357	2,741	2,172	934
Office and computing machines	443	541	685	758	1,140	1,025	985
Drugs and medicine	1,523	1,579	1,796	2,132	2,295	2,428	3,332
Industrial chemicals and synthetics	6,249	9,218	9,607	10,502	10,632	12,844	15,258
Instruments and related products	587	586	705	888	726	1,049	1,763
Engines and turbines	75	77	94	99	126	218	431
Other manufacturing industries	21,508	25,059	27,235	29,126	32,159	37,879	42,104
All service industries	1,089	1,330	1,899	2,082	2,479	2,943	5,988
Computer & data processing services	53	60	77	131	242	257	343
R&D and testing laboratories	55	57	63	75	76	83	95
Engineering, architectural & surveying services	129	143	155	121	169	200	823
Other service industries	852	1,070	1,604	1,755	1,992	2,403	4,727

¹ GNP implicit price deflators used to convert current dollars to constant 1982 dollars.

² U.S. Department of Commerce DOC-3 definitions.

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, "Foreign Direct Investment in the United States: Detail for Position and Balance of Payments Flows", *Survey of Current Business* (annual, August issues)

See figure 7-6.

Science & Engineering Indicators—1987

Appendix table 7-7. U.S. receipts and payments of royalties and fees associated with unaffiliated foreign residents:
1972-85

Years	All countries	Canada	West Germany	France	United Kingdom	Other Europe	Japan	Other countries
Millions of dollars								
Receipts:								
1972	\$655	\$38	\$56	\$42	\$63	\$150	\$240	\$66
1973	712	32	63	43	75	121	273	105
1974	751	38	78	46	71	137	249	132
1975	757	38	81	47	79	151	219	142
1976	822	45	83	57	72	157	246	162
1977	1,037	42	92	48	82	210	275	288
1978	1,180	61	119	47	93	206	343	311
1979	1,204	43	109	54	102	224	343	329
1980	1,305	68	145	144	113	120	403	312
1981	1,490	69	101	133	119	277	423	368
1982	1,669	71	105	119	122	266	502	484
1983	1,625	75	133	135	133	245	523	381
1984	1,619	82	118	103	132	274	549	361
1985	1,700	86	124	108	138	288	576	380
Payments:								
1972	139	6	29	13	44	35	6	6
1973	176	6	37	16	53	41	13	10
1974	186	7	34	14	67	43	12	9
1975	186	9	32	15	76	40	9	5
1976	189	9	34	14	77	35	13	7
1977	262	8	31	14	72	38	16	83
1978	277	10	27	16	84	47	15	78
1979	309	16	40	17	93	51	15	77
1980	297	18	61	31	96	55	20	16
1981	289	13	43	30	99	52	37	15
1982	292	10	35	22	94	56	31	44
1983	315	10	35	29	90	77	53	21
1984	362	11	58	35	85	88	63	22
1985	380	12	65	37	89	88	66	23

(continued)

Appendix table 7-7. (Continued)

Years	All countries	Canada	West Germany	France	United Kingdom	Other Europe	Japan	Other countries
Millions of dollars								
Millions of constant 1982 dollars ¹								
Receipts:								
1972	\$1,409	\$82	\$120	\$90	\$136	\$323	\$516	\$142
1973	1,437	65	127	87	151	244	551	212
1974	1,392	70	145	85	132	254	461	245
1975	1,276	64	137	79	133	255	369	239
1976	1,303	71	132	90	114	249	390	257
1977	1,541	62	137	71	122	312	409	428
1978	1,634	84	165	65	129	285	475	431
1979	1,532	55	139	69	130	285	437	419
1980	1,522	79	169	168	132	140	470	364
1981	1,586	73	107	142	127	295	450	392
1982	1,669	71	105	119	122	266	502	484
1983	1,565	72	128	130	128	236	504	367
1984	1,501	76	109	95	122	254	509	335
1985	1,524	77	111	97	124	258	516	341
Payments:								
1972	\$299	\$13	\$62	\$28	\$95	\$75	\$13	\$13
1973	355	12	75	32	107	83	26	20
1974	345	13	63	26	124	80	22	17
1975	314	15	54	25	128	67	15	8
1976	300	14	54	22	122	55	21	11
1977	389	12	46	21	107	56	24	123
1978	384	14	37	22	116	65	21	108
1979	393	20	51	22	118	65	19	98
1980	346	21	71	36	112	64	23	19
1981	308	14	46	32	105	55	39	16
1982	292	10	35	22	94	56	31	44
1983	303	10	34	28	87	74	51	20
1984	336	10	54	32	79	82	58	20
1985	341	11	58	33	80	79	59	21
Balance:								
1972	\$1,110	\$69	\$58	\$62	\$41	\$247	\$503	\$129
1973	1082	52	52	55	44	161	525	192
1974	1047	57	82	59	7	174	439	228
1975	963	49	83	54	5	187	354	231
1976	1004	57	78	68	-8	193	369	246
1977	1152	51	91	51	15	256	385	305
1978	1250	71	127	43	12	220	454	323
1979	1139	34	88	47	11	220	417	321
1980	1176	58	98	132	20	76	447	345
1981	1278	60	62	110	21	239	411	376
1982	1377	61	70	97	28	210	471	440
1983	1261	63	94	102	41	162	453	347
1984	1165	66	56	63	44	172	451	314
1985	1184	66	53	64	44	179	457	320

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, unpublished data

See figure 7-7.

Science & Engineering Indicators—1987

Appendix table 7-8. Technology sales agreements between Japan and the United States and other countries, new and old agreements, number of agreements, and payments made: 1975-85

Year	United States		Other major countries	
	New agreements	Old, in force agreements	New agreements	Old, in force agreements
Number of agreements				
1975	58	198	444	25
1976	166	251	515	29
1977	88	246	516	27
1978	102	281	625	41
1979	144	319	629	20
1980	164	488	872	29
1981	182	468	935	36
1982	206	448	872	39
1983	386	683	1,768	170
1984	197	554	1,150	88
1985	261	635	1,248	52
Value of agreements				
Millions of constant 1980 Yen				
1975	1,652	7,116	2,668	1,906
1976	2,254	7,117	1,423	3,559
1977	3,027	7,063	2,018	2,915
1978	6,524	7,487	2,460	2,995
1979	6,750	13,188	1,661	4,258
1980	6,100	16,000	3,600	5,000
1981	10,271	21,318	4,845	5,911
1982	8,183	25,785	7,422	10,466
1983	11,143	39,471	4,816	10,859
1984	11,269	50,182	4,441	11,837
1985	6,743	41,495	9,303	12,443

SOURCES: Statistics Bureau, Management and Coordination Agency, Government of Japan, unpublished statistics; updates and deflators provided by National Science Foundation, Division of International Programs, Tokyo Office

See table 7-1 in text.

Science & Engineering Indicators—1987

Appendix table 7-9. Technology purchase agreements between Japan and the United States and other countries, new and old agreements, number of agreements, and payments made: 1975-85

Year	United States		Other major countries	
	New agreements	Old, in force agreements	New agreements	Old, in force agreements
Number of Agreements				
1975	476	3,076	208	2,160
1976	313	3,042	163	1,622
1977	357	6,097	187	1,717
1978	497	3,136	331	1,611
1979	680	3,402	177	1,639
1981	396	3,696	179	1,672
1982	443	3,619	253	1,423
1983	554	4,144	235	1,523
1984	591	3,744	272	1,590
1985	716	4,006	297	1,489
Value of Agreements				
Millions of constant 1980 Yen				
1975	9,403	126,302	4,193	46,633
1976	15,421	120,522	3,321	41,637
1977	8,969	123,655	6,054	44,283
1978	28,984	102,674	6,631	37,968
1979	22,118	137,279	3,323	52,440
1980	19,900	134,000	4,900	47,500
1981	16,844	149,468	2,323	43,950
1982	32,414	145,342	4,943	46,483
1983	32,453	147,830	5,189	39,434
1984	22,050	157,787	4,336	34,826
1985	21,889	169,635	4,884	31,735

SOURCES: Statistics Bureau, Management and Coordination Agency, Government of Japan, unpublished statistics; updates and deflators provided by National Science Foundation, Division of International Programs, Tokyo Office

See table 7-1 in text

Science & Engineering Indicators—1987

Appendix table 7-10. Exports of high-technology products¹, by selected countries: 1965-84

Year	All Countries ²	France	West Germany	Japan	United Kingdom	United States	Other
Billions of dollars							
1965	16.42	1.23	2.70	1.19	2.01	4.66	4.63
1966	18.86	1.45	3.08	1.62	2.41	5.19	5.11
1967	21.19	1.61	3.44	1.89	2.40	6.11	5.74
1968	24.96	1.72	3.94	2.50	2.63	7.42	6.74
1969	29.40	2.06	4.71	3.36	2.99	8.50	7.79
1970	35.59	2.47	5.76	4.19	3.52	10.25	9.40
1971	37.70	2.82	3.51	5.13	4.21	11.23	10.79
1972	48.06	3.52	8.03	6.60	4.90	11.82	13.19
1973	64.62	4.90	11.67	8.54	6.19	15.99	17.33
1974	83.92	6.18	14.99	10.72	7.87	21.74	22.43
1975	88.32	7.20	14.57	10.68	8.86	23.19	23.82
1976	102.79	8.58	17.59	15.25	9.25	25.97	26.15
1977	117.25	9.79	20.22	18.07	11.08	27.75	30.33
1978	147.00	12.15	24.77	23.50	14.56	34.84	37.18
1979	179.67	16.25	30.25	25.76	18.07	43.52	45.83
1980	214.86	17.58	33.88	32.58	23.56	54.71	52.54
1981	219.37	16.60	31.56	40.26	20.39	60.39	50.17
1982	202.67	16.59	21.48	37.15	20.45	58.11	48.88
1983	223.44	16.71	31.81	43.96	19.46	60.16	51.34
1984	248.30	18.17	33.68	55.22	20.88	65.51	54.83
Billions of 1982 Dollars ³							
1965	48.61	3.64	8.01	3.52	5.94	13.80	13.70
1966	53.96	4.15	8.82	4.64	6.90	14.83	14.62
1967	58.96	4.48	9.57	5.25	6.67	17.01	15.98
1968	66.16	4.56	10.44	6.64	6.98	19.68	17.86
1969	73.92	5.17	11.84	8.44	7.52	21.37	19.58
1970	84.68	5.88	13.70	9.98	8.38	24.39	22.35
1971	84.94	6.36	7.92	11.56	9.49	25.31	24.30
1972	103.38	7.57	17.27	14.21	10.54	25.42	28.36
1973	130.44	9.90	23.56	17.25	12.49	32.27	34.98
1974	155.52	11.45	27.78	19.86	14.58	40.30	41.56
1975	148.91	12.15	24.56	18.01	14.93	39.11	40.15
1976	162.98	13.61	27.89	24.19	14.67	41.17	41.46
1977	174.27	14.55	30.06	26.85	16.47	41.25	45.09
1978	203.55	16.82	34.30	32.55	20.16	46.24	51.48
1979	228.67	20.68	38.50	32.78	22.99	55.39	58.33
1980	250.65	20.50	39.52	38.01	27.49	63.82	61.30
1981	233.47	17.67	33.59	42.85	21.70	64.27	53.39
1982	202.67	16.59	21.48	37.15	20.45	58.11	48.88
1983	215.14	16.09	30.63	42.32	18.73	57.92	49.43
1984	229.71	16.81	31.16	51.08	19.32	60.61	50.73

(continued)

Appendix table 7-10. (Continued)

Year	All Countries ²	West Market shares (percent)			United Kingdom	United States	Other
		France	Germany	Japan			
1965	100.00	7.49	16.47	7.24	12.22	28.40	28.18
1966	100.00	7.69	16.35	8.61	12.78	27.49	27.09
1967	100.00	7.60	16.22	8.90	11.32	28.86	27.10
1968	100.00	6.89	15.78	10.03	10.55	29.74	27.00
1969	100.00	7.00	16.02	11.42	10.17	28.91	26.48
1970	100.00	6.94	16.18	11.78	9.90	28.81	26.40
1971	100.00	7.49	9.32	13.61	11.17	29.80	28.61
1972	100.00	7.33	16.71	13.74	10.19	24.59	27.44
1973	100.00	7.59	18.07	13.22	9.57	24.74	26.81
1974	100.00	7.36	17.86	12.77	9.37	25.91	26.72
1975	100.00	8.16	16.49	12.10	10.03	26.26	26.97
1976	100.00	8.35	17.11	14.84	9.00	25.26	25.44
1977	100.00	8.35	17.25	15.41	9.45	23.67	25.87
1978	100.00	8.26	16.85	15.99	9.91	23.70	25.29
1979	100.00	9.04	16.83	14.34	10.05	24.22	25.51
1980	100.00	8.18	15.77	15.16	10.97	25.46	24.46
1981	100.00	7.57	14.39	18.35	9.29	27.53	22.87
1982	100.00	8.19	10.60	18.33	10.09	28.67	24.12
1983	100.00	7.48	14.24	19.67	8.71	26.92	22.98
1984	100.00	7.32	13.57	22.24	8.41	26.38	22.08

¹ Uses the DOC-3 definition of "high-technology products". See page 127 in text.

² "All countries" includes, in addition to those shown here, Austria, Belgium, Canada, Denmark, Italy, The Netherlands, Norway, Sweden, and Switzerland.

³ Current-dollar figures are transformed into constant terms using the GNP deflator.

SOURCE: Victoria L. Hatter, "U.S. High Technology Trade and Competitiveness," Staff Report, Office of Trade and Investment Analysis, International Trade Administration, U.S. Department of Commerce, February, 1985; Office of Trade and Investment Analysis, International Trade Administration, U.S. Department of Commerce, unpublished statistics (June, 1987)

See figure 7-8.

Science & Engineering Indicators—1987

Appendix table 7-11. U.S. trade in high-technology¹ product groups, by region: 1978-86

Year	Japan			Other Developed Countries			East Asian NICs ²			Other Countries		
	Exports	Imports	Balance	Exports	Imports	Balance	Exports	Imports	Balance	Exports	Imports	Balance
Billions of constant 1982 ³ dollars												
1978	3.27	9.86	6.59	24.32	10.57	13.75	3.34	4.85	1.51	44.90	23.25	21.65
1979	6.14	8.96	2.82	26.73	11.56	15.17	4.64	5.11	0.48	50.76	23.84	26.91
1980	6.39	9.14	2.75	31.49	13.34	18.15	5.27	5.47	0.20	58.56	27.22	31.34
1981	7.16	11.42	4.26	31.29	13.68	17.61	4.59	5.84	1.25	59.68	30.16	29.52
1982	6.15	11.25	5.11	27.46	12.40	15.05	4.53	5.88	1.34	53.58	28.65	24.94
1983	6.55	13.90	7.35	28.50	12.35	16.15	5.50	7.89	2.39	52.43	31.97	20.45
1984	7.77	20.56	12.79	29.62	16.96	12.66	5.92	10.37	4.46	54.81	44.75	10.06
1985	7.29	22.57	15.27	30.38	19.06	11.32	5.62	9.98	4.37	55.74	48.10	7.64
1986	7.00	25.67	18.67	33.03	21.05	11.98	5.76	11.89	6.13	57.51	53.64	3.87
Billions of dollars												
1978	2.36	7.12	4.76	17.57	7.63	9.93	2.41	3.50	1.09	32.43	16.79	15.63
1979	4.82	7.04	2.22	21.00	9.08	11.92	3.64	4.02	0.38	39.88	18.74	21.15
1980	5.48	7.84	2.36	26.99	11.44	15.56	4.51	4.69	0.17	50.20	23.33	26.87
1981	6.73	10.73	4.00	29.40	12.85	16.55	4.32	5.49	1.17	56.08	28.34	27.74
1982	6.15	11.25	5.11	27.46	12.40	15.05	4.53	5.88	1.34	53.58	28.65	24.94
1983	6.81	14.44	7.63	29.60	12.83	16.77	5.71	8.19	2.48	54.45	33.21	21.24
1984	8.38	22.18	13.80	31.96	18.29	13.66	6.38	11.19	4.81	59.13	48.27	10.85
1985	8.13	25.17	17.03	33.88	21.26	12.62	6.26	11.13	4.87	62.16	53.64	8.52
1986	8.02	29.42	21.40	37.86	24.13	13.73	6.61	13.63	7.02	65.91	61.48	4.43

¹ U.S. Department of Commerce DOC-3 definitions.

² Converted to constant dollars using the GNP implicit price deflator.

³ Newly industrialized countries in East Asia include Hong Kong, Republic of Korea, Singapore, and Taiwan.

SOURCES: U.S. Department of Commerce, International Trade Administration, *U.S. Trade Performance in 1985 and Outlook* (October, 1986); U.S. Department of Commerce, International Trade Administration, Office of Trade and Investment Analysis, unpublished data.

Science & Engineering Indicators—1987

Appendix table 7-12. Exports of selected high-technology products, volume and market shares, selected countries: 1975, 1984

Product group	United States		Japan		West Germany		France		United Kingdom	
	1975	1984	1975	1984	1975	1984	1975	1984	1975	1984
Millions of dollars										
All high technology products	23,193.5	65,510.0	10,683.7	55,216.6	14,566.6	33,684.2	7,203.7	18,172.8	8,855.7	20,879.3
Communications equipment & electronic components	3,884.2	14,425.0	4,749.5	29,195.4	3,187.5	6,712.3	1,292.7	3,185.1	1,426.9	3,677.9
Aircraft & parts	7,119.2	13,540.1	29.6	143.2	465.3	4,095.0	865.0	3,181.9	1,625.0	3,943.4
Office, computing, & accounting machines	2,790.9	14,698.9	1,006.7	9,884.7	1,570.1	3,986.7	731.8	2,264.1	1,027.3	3,836.1
Market shares (percent)										
All high technology products	26.3	26.4	12.1	22.2	16.5	13.6	8.2	7.3	10.0	8.4
Communications equipment & electronic components	18.8	21.1	23.9	36.6	16.1	12.2	6.5	5.2	7.2	6.3
Aircraft & parts	62.2	45.9	0.3	0.6	4.1	15.6	7.6	9.4	14.3	15.5
Office, computing, & accounting machines	30.1	36.7	11.0	17.5	17.2	12.2	8.0	6.2	11.2	9.0

SOURCE: Victoria L. Hatter, U.S. Department of Commerce, International Trade Administration, Office of Trade and Investment Analysis, unpublished tabulations (June, 1987).

See figure 7-9.

Science & Engineering Indicators—1987

Appendix table 7-13. Direct investment positions abroad and shares of total international direct investment, major investing countries and world total, 1973-84

Country of origin	1973	1978	1981	1984	Average annual growth	
					1973-78	1973-84
	Billions of constant 1982 dollars ¹				Percent	
All countries	430.2	524.6	580.7	620.1	4.1	3.4
Total, major investing countries	388.8	474.1	527.1	532.4	4.0	2.9
United States	204.5	225.3	243.0	213.0	2.0	0.4
United Kingdom	54.3	56.9	69.7	77.6	0.9	3.3
West Germany	24.0	44.0	48.4	53.2	12.9	7.5
Japan	20.8	37.1	39.4	49.5	12.3	8.2
Netherlands	31.1	32.8	34.5	37.9	1.1	1.8
Switzerland	20.6	38.5	38.7	36.8	13.3	5.4
Canada	15.7	18.8	27.2	33.9	3.6	7.2
France	17.8	20.6	26.1	30.4	3.0	5.0
Other countries	41.4	50.5	53.6	87.7	4.1	7.1

¹ Data converted to 1982 dollars using the U.S. GNP deflator.

SOURCES: Foreign countries (1973-1981): U.S. Department of Commerce, International Trade Administration, *International Direct Investment: Global Trends and the U.S. Role* (August, 1984); foreign countries, later years: derived by adding direct investment outflows reported to the IMF and published in IMF, *Balance of Payments Statistics Yearbook, Part 2*, 1985; United States: U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business* (June, 1986), p. 30

See figures 7-10, 7-11.

Science & Engineering Indicators—1987

Appendix table 8-1. Various segments of U.S. public attentive to or interested in science and technology: 1985

Segment of public	Attentive public	Interested public	Remaining public	N
	Percent			
Total public	21	26	53	2,005
Age:				
18-24	21	23	56	326
25-34	19	30	51	474
35-44	22	24	53	370
45-64	22	27	51	520
65 + ...	19	22	59	315
Gender:				
Female	17	24	59	1,054
Male	25	27	47	950
Education:				
Less than high school	12	21	67	507
High school graduate	21	27	52	1,006
AA Degree	29	25	46	137
BA Degree	33	28	39	229
Graduate degree	28	28	44	121

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-1 in text.

Science & Engineering Indicators—1987

Appendix table 8-2. Reported understanding of various aspects of science and technology: 1985

Segment of public	Scientific study	DNA	Molecule	Computer software	Radiation	GNP	How a telephone works	N
	Percent claiming clear understanding							
Total public	29	14	27	20	29	23	18	2,005
Age:								
18-24	34	17	30	20	27	23	15	326
25-34	35	25	36	26	28	25	20	474
35-44	32	17	33	25	35	26	19	370
45-64	30	5	21	20	27	22	19	520
65 + ...	13	6	16	7	26	20	15	315
Gender:								
Female	27	13	22	16	24	15	12	1,054
Male	32	16	33	25	33	32	24	950
Education:								
Less than high school	13	4	8	2	21	8	17	507
High school graduate	27	12	24	20	26	20	16	1,006
AA degree	30	16	41	28	29	30	20	137
BA degree	57	31	58	40	44	47	25	229
Graduate degree	61	39	62	55	55	60	26	121

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-2 in text.

Science & Engineering Indicators—1987

Appendix table 8-3. Actual understanding of various aspects of science and technology: 1985

Segment of public	Molecule	Scientific study	How a telephone works	N
Percent responding correctly				
Total public	10	13	8	2,005
Age:				
18-24	13	16	6	326
25-34	14	14	11	474
35-44	13	17	10	370
45-64	5	11	7	520
65 + ...	4	4	3	315
Gender:				
Female	8	13	2	1,054
Male	12	13	14	950
Education:				
Less than high school	2	2	2	507
High school graduate	6	13	7	1,006
AA degree	15	16	11	137
BA degree	22	22	16	229
Graduate degree	27	31	20	121

"In your own words, could you tell me what a molecule is?"

¹ Question was asked only of those who previously had stated they had either a "clear understanding" or a "general sense" of this aspect. Percentages are based on total sample. Responses were coded at the Public Opinion Laboratory, with tests of intercoder reliability.

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-3 in text.

Science & Engineering Indicators—1987

Appendix table 8-4. Reported understanding of various aspects of science and technology by Japanese: 1987

Aspect	Understand	Certain extent	Heard before	Don't understand
Percent				
GNP	27	19	28	27
Computer software	21	19	31	29
Optical fibers	21	20	36	23
IC,LSI	19	16	31	34
Data base	13	12	29	47
DNA	8	7	19	67
N = 2,334				

"To what degree do you understand the following words?"

SOURCE: Office of the Prime Minister of Japan, Public Relations Office, *Public Opinion Survey on Science, Technology, and Society* (1988)

Science & Engineering Indicators—1987

Appendix table 8-5. Public¹ using various information sources: 1985

Segment of public	Watch science television	Visit public library	Visit zoo or aquarium	Visit science museum ²	Visit art museum	Read science magazines	N
	Percent						
Total public	71	67	48	38	31	16	2,005
Age:							
18-24	60	79	57	46	41	12	326
25-34	71	77	65	49	36	19	474
35-44	76	73	56	45	36	20	370
45-64	71	57	37	29	24	15	520
65 + ...	74	51	22	19	21	12	315
Gender:							
Female	68	70	49	34	33	15	1,054
Male	73	64	48	39	30	18	950
Education:							
Less than high school	61	46	32	18	12	7	507
High school graduate	71	70	48	37	30	15	1,006
AA Degree	78	82	67	54	46	22	137
BA Degree	80	85	67	62	55	27	229
Graduate degree	84	88	68	62	62	32	121

¹ In the case of science magazines and science television this is the percent who use them at least occasionally. In other cases, it is those who had used the source at least once in the past year.

² Includes visits to a "Science or technology museum" or a "Natural history museum."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-5 in text.

Science & Engineering Indicators—1987

Appendix table 8-6. Weekly science and health sections in U.S. daily newspapers: 1977-86

Year ¹	Science ²	Health ³
1977	0	0
1978	1	0
1979	1	0
1980	1	0
1981	4	1
1982	7	1
1983	16	2
1984	27	4
1985	45	15
1986	61	20

¹ As of September of each year.

² Science sections including health and fitness. Groups of newspapers with the same science editor were counted as one newspaper. Multiple weekly columns were counted separately.

³ Health and fitness exclusively.

SOURCE: Scientists' Institute for Public Information, *SIFI Scope*, vol. 14, No. 4, Autumn 1986

See figure 8-1.

Science & Engineering Indicators—1987

Appendix table 8-7. Computer use at home and at work: 1985

Segment of public	At home and work	At work	At home	No use	N
	Percent				
Total public	5	19	7	69	2,005
Age:					
18-24	3	24	7	66	326
25-34	8	26	7	60	474
35-44	9	22	10	59	370
45-64	3	18	6	72	520
65 + ...	0	3	3	94	315
Gender:					
Female	4	18	6	72	1,054
Male	6	21	7	66	950
Education:					
Less than high school	0	7	5	89	507
High school graduate	3	20	6	71	1,006
AA Degree	9	27	13	51	137
BA Degree	12	33	7	48	229
Graduate degree	17	31	12	40	121

Note: Cases which indicated that "Entertainment" was primary use of computer were placed in "Does not use" category.

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-6 in text.

Science & Engineering Indicators—1987

Appendix table 8-8. Public assessment of beneficial versus harmful results of scientific research: 1985

Segment of public	Benefits substan'y greater	Benefits slightly greater	Benefits equal harms ¹	Harms slightly greater	Harms substan'y greater	Don't know	N
	Percent						
Total public	44	24	4	13	6	9	2,005
Age:							
18-24	37	29	2	22	5	5	326
25-34	46	26	2	16	5	5	474
35-44	54	21	6	10	4	5	370
45-64	46	20	4	10	8	12	520
65 + ...	31	23	7	9	9	21	315
Gender:							
Female	40	25	4	14	6	11	1,054
Male	48	22	4	13	6	7	950
Education:							
Less than high school	20	21	7	19	13	20	507
High school graduate	46	25	4	13	4	8	1,006
AA Degree	54	26	3	7	5	5	137
BA Degree	64	23	1	7	3	2	229
Graduate degree	71	20	2	3	1	3	121
Attentiveness:							
Attentives	55	23	3	10	4	5	417
Interested	48	24	5	11	4	8	517
Remaining	37	26	5	15	7	10	1,071

"People have frequently noted that scientific research has produced both beneficial and harmful consequences. Would you say that, on balance, the benefits of scientific research have outweighed the harmful results, or that the harmful results of scientific research have outweighed its benefits?"

¹ Volunteered by respondent.

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-7 in text.

Science & Engineering Indicators—1987

Appendix table 8-9. Benefits and harms from scientific advance, for various countries: 1981-83

Country	Will help	Will harm	Both	No answer/ Don't know
	Percent			
Japan	23.4	9.6	57.4	9.6
United Kingdom	48.3	21.8	25.9	4.1
France	36.9	21.3	36.2	5.7
West Germany	32.4	21.1	40.0	6.5
Italy	39.4	20.2	35.9	4.5
United States	54.3	19.0	21.5	5.2
Canada	44.7	22.3	29.4	3.5
Lebanon	52.2	9.0	36.7	2.1
Kuwait	69.1	4.2	25.5	1.2
Australia	45.0	26.4	25.2	3.3
Netherlands	21.9	36.4	33.6	8.1
Denmark	30.9	20.6	42.3	6.2
Belgium	25.1	17.5	46.4	11.1
Spain	44.0	18.0	31.0	7.0
Ireland	37.8	27.5	26.7	8.0
Ulster	37.0	22.0	35.0	6.0
Sweden	35.0	21.0	40.0	4.0

"In the long run, do you think the scientific advances we're making will help or harm mankind?"

Note: Data are from 1981, except for Canada (1982) and Kuwait, Lebanon, and Australia (1983)

SOURCE: Internationales Institut für Empirische Sozialökonomie, Stadtbergen, FRG, unpublished tabulations

See figure O-33 in Overview.

Science & Engineering Indicators—1987

Appendix table 8-10. Public expectations concerning future outcomes, by attentiveness: 1985

Outcome	Total public	Attentive public	Interested public	Remaining public
Percent				
A cure for the common forms of cancer:				
Very likely	55	63	57	51
Possible	37	31	35	40
Not at all likely	6	4	7	3
Don't know	2	2	1	3
A war in space:				
Very likely	12	13	11	13
Possible	34	36	28	36
Not at all likely	50	50	57	47
Don't know	4	2	3	5
A safe method for the long-term storage or disposal of waste products from nuclear power plants:				
Very likely	36	41	40	33
Possible	42	37	36	46
Not at all likely	18	20	19	17
Don't know	4	2	4	5
The accidental release of a genetically engineered microbe into the environment:				
Very likely	17	20	15	18
Possible	50	56	49	48
Not at all likely	20	17	25	19
Don't know	13	7	11	16
The placement of a scientific or mining colony on the moon:				
Very likely	32	37	32	30
Possible	39	40	42	38
Not at all likely	25	20	23	28
Don't know	4	3	3	5
Another nuclear power plant accident like Three Mile Island:				
Very likely	46	47	44	47
Possible	41	45	44	38
Not at all likely	9	6	9	11
Don't know	4	3	3	5
The accidental release in the United States of a toxic chemical that will result in numerous deaths:				
Very likely	42	44	41	42
Possible	42	45	42	42
Not at all likely	12	9	15	12
Don't know	4	2	2	5
The development of genetically engineered bacteria to eat or destroy toxic chemicals:				
Very likely	32	41	37	26
Possible	43	42	38	47
Not at all likely	17	13	18	17
Don't know	8	5	8	10
The landing of a manned mission on Mars:				
Very likely	27	32	28	24
Possible	41	41	41	41
Not at all likely	29	25	29	30
Don't know	4	3	3	4
A cure for the disease AIDS:				
Very likely	49	58	54	44
Possible	38	31	34	42
Not at all likely	9	9	10	9
Don't know	4	2	3	5

"Do you think that it is very likely, possible but not too likely, or not at all likely that this result will occur in the next 25 years?"

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-9 in text.

Science & Engineering Indicators—1987

Appendix table 8-11. Japanese public expectations concerning future outcomes: 1987

Outcome	Most probably will occur	Possibility is low	Will not occur	Don't know
	Percent			
Progress in curing cancer	74	17	4	5
Automatic translation devices for international travelers	62	17	7	13
Progress in curing AIDS	58	22	7	12
Earthquake prediction	52	31	9	8
Safe processing method for atomic waste	44	29	12	14
Progress in curing senility	34	37	17	11
Landing people on Mars	33	29	21	17
Living in space stations	23	32	30	15
Cities in the ocean	18	33	35	15
N =	2,334			

"Do you think that the following things will take place in the next 25 years?"

SOURCE: Office of the Prime Minister of Japan, Public Relations Office, *Public Opinion Survey on Science, Technology, and Society* (1988)

Science & Engineering Indicators—1987

Appendix table 8-12. Public indicating "a great deal of confidence" in the people running selected institutions: 1973-86

Institution	1973	1974	1975	1976	1977	1978	1980	1982	1983	1984	1986
	Percent										
Medicine	54	60	50	54	51	46	52	46	51	50	46
Scientific community	37	45	38	43	41	36	41	38	41	44	39
Education	37	49	31	37	41	28	30	33	29	28	28
Organized religion	35	44	24	30	40	31	35	32	28	31	25
Military	32	40	35	39	36	29	28	31	29	36	31
Major companies	29	31	19	22	27	22	27	23	24	30	24
Press	23	26	24	28	25	20	22	18	13	17	18
TV	19	23	18	19	17	14	16	14	12	14	15
Organized labor	15	18	10	12	15	11	15	12	8	8	8
Executive branch of the federal government	29	14	13	13	28	12	12	19	13	18	21
Congress	23	17	13	14	19	13	9	13	10	12	16
U.S. Supreme Court	31	33	31	35	35	28	25	30	28	33	30
Banks and financial institutions	NA	NA	32	39	42	33	32	25	24	31	21
N =	1,504	1,484	1,490	1,499	1,530	1,532	1,468	1,506	1,599	989	1,470

"I am going to name some institutions in this country. As far as the people running these institutions are concerned, would you say you have a great deal of confidence, only some confidence, or hardly any confidence at all in them?"

SOURCES: James A. Davis, Tom W. Smith, *General Social Surveys Cumulative Codebook, 1972-1985*, Roper Center, pp. 166-169; unpublished 1986 data provided by Tom W. Smith

See figure 8-2.

Science & Engineering Indicators—1987

Appendix table 8-13. Public image of scientists: 1985

Segment of public	Percent agreeing that scientists		N
	Work for good of humanity	Have power that is dangerous	
Total public	80	55	2,005
Age:			
18-24	83	55	362
25-34	79	52	474
35-44	78	46	370
45-64	80	55	520
65 + ...	81	66	315
Gender:			
Female	81	58	1,054
Male	78	52	950
Education:			
Less than high school	81	69	507
High school graduate	80	56	1,006
AA Degree	82	42	137
BA Degree	80	36	229
Graduate degree	73	34	121

"For each statement, tell me if you generally agree or generally disagree."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-12 in text.

Science & Engineering Indicators—1987

Appendix table 8-14. Public acceptance of scientific conclusions: 1985

Segment of public	Percent						N
	A	B	C	D	E	F	
Total public	44	46	53	95	45	79	2,005
Age:							
18-24	41	42	50	97	51	79	326
25-34	48	42	56	97	51	81	474
35-44	50	40	53	93	51	78	370
45-64	43	52	52	94	40	78	520
65 + ...	35	53	50	93	34	82	315
Gender:							
Female	33	44	54	94	41	77	1,054
Male	56	48	51	96	50	82	950
Education:							
Less than high school	29	46	36	92	39	72	507
High school graduate	44	44	55	95	40	79	1,006
AA Degree	50	49	63	98	49	82	137
BA Degree	63	52	67	97	64	88	229
Graduate degree	64	48	70	98	72	92	121

Note: A = Disagree that "Rocket launchings and other space activities have caused changes in our weather."

B = Disagree that "It is likely that some of the unidentified flying objects that have been reported are really space vehicles from other civilizations."

C = Disagree that "Some numbers are especially lucky for some people."

D = Agree that "Smoking causes serious health problems."

E = Agree that "Human beings as we know them today developed from earlier species of animals."

F = Agree that "The continents on which we live have been moving their location for millions of years and will continue to move in the future."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-13 in text.

Science & Engineering Indicators—1987

Appendix table 8-15. Public views of the limits of science: 1985

Segment of public	A	B	C	D	N
	Percent				
Total public	59	75	8	8	2,005
Age:					
18-24	66	73	11	10	326
25-34	57	77	6	6	474
35-44	53	75	6	8	370
45-64	58	76	6	8	520
65 + ...	62	73	12	11	315
Gender:					
Female	59	74	10	9	1,054
Male	59	76	6	7	950
Education:					
Less than high school	67	76	17	14	507
High school graduate	59	74	6	8	1,006
AA Degree	57	74	4	4	137
BA Degree	49	78	2	4	229
Graduate degree	45	73	5	1	121

Note: A = Agree that "Scientists will never be able to understand the working of the human mind as well as they understand the physical world."

B = Agree that "There are some good ways of treating sickness that medical science does not recognize."

C = Responded 'Yes' to "Do you sometimes decide to do or not do something because your astrological signs for the day are favorable or unfavorable?"

D = Stated that "Astrology is very scientific."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-15 in text.

Science & Engineering Indicators—1987

Appendix table 8-16. Public considering U.S. ahead of other countries in science and technology, by attentiveness: 1985

Area and country	Total public	Attentive public	Interested public	Remaining public
	Percent			
Basic scientific achievements:				
West Germany	58	66	61	54
France	75	82	77	71
Japan	36	41	36	34
Great Britain	70	78	74	66
Soviet Union	43	55	43	39
Military technology:				
West Germany	70	75	75	66
France	80	84	86	77
Japan	73	80	76	69
Great Britain	76	83	79	73
Soviet Union	33	41	34	29
Civilian or industrial technology:				
West Germany	49	47	50	49
France	73	77	79	69
Japan	11	10	12	12
Great Britain	69	75	75	64
Soviet Union	75	83	77	71
N =	2,005	417	517	1,071

"In terms of basic scientific achievements, would you say that the United States is ahead of West Germany, behind West Germany or at about the same level?"

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-16 in text.

Science & Engineering Indicators—1987

Appendix table 8-17. Japanese public's ranking of various countries on various aspects of science and technology: 1987

Country	Basic science and technology	Industrial technology	Technology related to everyday living
	Average ranking		
United States	1.6	1.8	1.8
Japan	2.8	2.0	2.3
West Germany	3.7	3.7	3.8
U.S.S.R.	3.4	4.0	4.6
United Kingdom	4.6	4.5	4.1
France	5.1	4.9	4.4

N = 2,334

"For each of the areas listed below please rank the following countries according to their degree of progress."

SOURCE: Office of the Prime Minister of Japan, Public Relations Office, *Public Opinion Survey on Science, Technology, and Society* (1988)

See table 8-17 in text.

Science & Engineering Indicators—1987

Appendix table 8-18. Public support for basic scientific research: 1985

Segment of public	Strongly agree	Agree	Don't know	Disagree	Strongly disagree	N
	Percent					
Total public	9	70	5	15	1	2,005
Age:						
18-24	14	65	5	15	1	326
25-34	14	71	2	12	1	474
35-44	9	72	5	14	1	370
45-64	5	73	5	17	0	520
65 + ...	5	65	10	19	0	315
Gender:						
Female	7	68	8	16	1	1,054
Male	11	71	2	15	1	950
Education:						
Less than high school	5	65	9	20	0	507
High school graduate	7	71	5	16	1	1,006
AA degree	9	78	2	11	0	137
BA degree	19	68	2	10	1	229
Graduate degree	19	70	2	8	0	121

"Even if it brings no immediate benefits, scientific research which advances the frontiers of knowledge is necessary and should be supported by the Federal Government."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology, 1985* (1988)

See table 8-18 in text.

Science & Engineering Indicators—1987

Appendix table 8-19. Public willingness to restrain scientific studies: 1979-85

Subject	1979	1983	1985
— Percent willing to prohibit —			
Studies that might enable most people in society to live to be 100 or more	29	32	26
Studies that could allow parents to select the sex of their child	NA	62	NA
Studies that might allow scientists to create new forms of life	65	NA	NA
Studies that might allow scientists to create new forms of plant and animal life	NA	46	42
Studies that might lead to precise weather control and modification	28	NA	36
Studies that might discover intelligent beings in outer space	36	38	29
Studies that cause pain or injury to animals like dogs and chimpanzees, but which produce new information about human disease or health problems	NA	NA	30
Studies that are designed to create new biological or chemical weapons	NA	NA	66
N =	1,635	1,630	2,005

"For each study, please tell me whether you think scientists should or should not be allowed to conduct that kind of research. If you don't care one way or the other, just give me that answer."

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-19 in text.

Science & Engineering Indicators--1987

Appendix table 8-20. Public assessment of three policy areas, by demographic group: 1985

Segment of public	Space exploration						N
	Benefits substantially exceed costs	Benefits only slightly exceed costs	Benefits & costs about equal (volunteered by respondent)	Costs only slightly exceed benefits	Costs substantially exceed benefits	Don't know	
	Percent						
Total public	26	27	2	15	24	5	2,005
Age:							
18-24	24	30	1	19	22	4	326
25-34	29	27	3	16	22	4	474
35-44	28	31	1	12	25	3	370
45-64	25	24	3	16	26	5	520
65 + ...	23	25	4	14	26	9	315
Gender:							
Female	20	24	3	18	30	6	1,054
Male	33	31	2	12	18	4	950
Education:							
Less than high school	20	25	3	17	26	8	507
High school graduate	26	27	2	16	26	4	1,006
AA Degree	26	32	2	14	25	1	137
BA Degree	35	29	2	13	17	5	229
Graduate Degree	38	25	3	15	17	3	121

(Continued)

Appendix table 8-20. (Continued)

Genetic engineering research							
	Benefits are substantially greater than risks	Benefits are only slightly greater than risks	Benefits & risks about equal (volunteered by respondent)	Risks are only slightly greater than benefits	Risks are substantially greater than benefits	Don't know	N
	Percent						
Total public	23	27	2	14	24	11	2,005
Age:							
18-24	24	29	2	22	17	6	326
25-34	27	27	2	12	27	6	474
35-44	23	24	2	15	26	10	370
45-64	20	28	2	14	23	13	520
65 + ...	17	23	1	9	29	21	315
Gender:							
Female	19	25	2	16	27	12	1,054
Male	26	28	2	13	22	9	950
Education:							
Less than high school	19	29	1	13	23	15	507
High school graduate	20	24	2	14	27	12	1,006
AA Degree	25	24	0	21	25	5	137
BA Degree	29	29	2	16	19	5	229
Graduate Degree	36	30	2	10	16	6	121
Nuclear power							
	Benefits are substantially greater than risks	Benefits are only slightly greater than risks	Benefits & risks about equal (volunteered by respondent)	Risks are only slightly greater than benefits	Risks are substantially greater than benefits	Don't know	N
	Percent						
Total public	27	22	1	14	31	5	2,005
Age:							
18-24	18	23	1	17	39	3	326
25-34	22	20	1	16	38	4	474
35-44	27	24	2	17	27	3	370
45-64	30	24	2	11	29	4	520
65 + ...	39	20	1	11	19	11	315
Gender:							
Female	18	22	2	17	35	6	1,054
Male	37	23	1	10	26	3	950
Education:							
Less than high school	28	24	1	15	25	7	507
High school graduate	26	22	2	13	33	4	1,006
AA Degree	31	20	0	15	31	3	137
BA Degree	28	20	1	13	36	3	229
Graduate Degree	27	23	1	17	31	2	121

"In your opinion, have the costs of space exploration exceeded its benefits, or have the benefits of space exploration exceeded its costs?"

SOURCE: Jon D. Miller, *Public Attitudes Toward Science and Technology*, 1985 (1988)

See table 8-21 in text.

Science & Engineering Indicators—1987

Appendix table 8-21. Public reactions to Shuttle Challenger accident: February 1986 and June 1986

Question and response	February	June
	— Percent —	
"Generally speaking, would you say that this accident has been a major setback for the space program, a minor setback, or not really a setback at all?"		
Major	37	66
Minor	45	26
No setback	17	7
Don't know	2	1
"If additional funds are needed to modify the shuttle program or to get it back on schedule, would you personally support increased Federal funds for the shuttle program, oppose additional funds, or would it make no difference to you?"		
Support	50	49
Oppose	22	23
No difference	26	26
No answer	3	2
"The accident reflects a basic design error or flaw in the shuttle. Do you strongly agree, agree, disagree, or strongly disagree.?"		
Strongly agree	8	17
Agree	42	62
Disagree	40	18
Strongly disagree	6	2
Don't know	5	2
"The space shuttle is such a complex machine that accidents will continue to occur from time to time."		
Strongly agree	8	7
Agree	75	76
Disagree	15	16
Strongly disagree	1	1
Don't know	1	1
"The space program should reduce the number of manned shuttle flights and rely more on unmanned vehicles."		
Strongly agree	4	4
Agree	27	39
Disagree	55	49
Strongly disagree	10	4
Don't know	5	4
"The space shuttle is still an outstanding example of American technology."		
Strongly agree	32	24
Agree	65	73
Disagree	2	3
Strongly disagree	0	0
Don't know	1	1
"Do you think that manned shuttle flights will start again?"		
Yes	98	98
No	1	1
Don't know	1	1

N = 1,111 (the same set of respondents in February and in June)

SOURCE: Jon D. Miller, *The Impact of the Challenger Accident on Public Attitudes toward the Space Program*, Report to the National Science Foundation (January, 1987)

See table 8-22 in text.

Science & Engineering Indicators—1987

Appendix II

Contributors and Reviewers

Contributors and Reviewers

The following persons contributed to this report, by reviewing chapters or sections, by providing data, or by otherwise assisting in its preparation. Their help is greatly appreciated.

- Catherine Ailes, SRI International
 Jane Armstrong, Education Commission of the States
 L. Vaughn Blankenship, University of Illinois
 Daniel Boy, Fondation Nationale des Sciences Politiques, Paris
 Paul Brinkman, National Center for Higher Education Management Systems
 Mark Carpenter, CHI Research, Inc.
 Alok Chakrabarti, Drexel University
 Marjorie Chandler, U.S. Department of Education
 Pamela Chavez, U.S. Department of State
 Nita Congress, Evaluation Technologies Incorporated
 Mark Dibner, North Carolina Biotechnology Center
 Robert Dauffenbach, Oklahoma State University
 Lester Davis, U.S. Department of Commerce
 David Drew, Claremont Graduate School
 Brian Duff, National Air and Space Museum
 James Ebert, Carnegie Institution of Washington
 Richard Ellis, Engineering Manpower Commission
 Robert Evenson, Yale University
 Alan Fechter, National Academy of Sciences
 Michael Finn, Oak Ridge Associated Universities
 Carol Frances, Carol Frances + Associates
 Helen Gee, National Institutes of Health
 Roger Geiger, The Pennsylvania State University
 Aaron Gellman, Gellman Research Associates, Inc.
 Jerilee Grandy, Educational Testing Service
 Lee Hansen, University of Wisconsin
 Victoria Hatter, U.S. Department of Commerce
 Tom Hilton, Educational Testing Service
 Patricia Hughes, National Science Foundation
 Dieter Jaufmann, Internationales Institut für Empirische Sozialökonomie, Stadtbergen, West Germany
 Fred Jerome, Scientists' Institute for Public Information
 Dennis Jones, National Center for Higher Education Management Systems
 Roubina Khoylian, Venture Economics, Inc.
 Ann Lanier, National Science Foundation
 Charles F. Larson, Industrial Research Institute, Inc.
 Jane Maddocks, Foxon-Maddocks Associates
 Elizabeth Martin, Bureau of the Census, U.S. Department of Commerce
 Shirley McBay, Massachusetts Institute of Technology
 Margaret O. Meredith, National Science Foundation
 Jon D. Miller, Northern Illinois University
 Jane Myers, U.S. Patent and Trademark Office, U.S. Department of Commerce
 Joseph Pelzman, George Washington University
 Lois Peters, Rensselaer Polytechnic Institute
 Martin Pfaff, Universität Augsburg
 Don I. Phillips, National Academy of Sciences
 Bruce Phillips, U.S. Small Business Administration
 Andrew Porter, Michigan State University
 Michael Radnor, Northwestern University
 Senta Raizen, National Research Council
 Frank Rhoades, Cornell University
 Mary Budd Rowe, University of Florida
 James Rutherford, American Association for the Advancement of Science
 Mamamichi Sasaki, Hyogo Ko University, Japan
 Richard Shavelson, The RAND Corporation
 Tom Smith, National Opinion Research Center, University of Chicago
 Lowell Steele, consultant
 Paula Stephan, Georgia State University
 Tatsuzo Suzuki, The Institute of Statistical Mathematics, Tokyo
 David J. Teece, University of California Berkeley
 Kenneth Travers, University of Illinois Urbana
 Betty Vetter, Commission on Professionals in Science and Technology
 Atul Wad, Northwestern University
 Amy Walton, Jet Propulsion Laboratory, California Institute of Technology
 Spencer Weart, American Institute of Physics
 Iris Weiss, Horizon Research, Inc.
 Gunnar Westholm, Organisation for Economic Co-operation and Development
 Robert R. Wright (deceased), consultant

Subject Index

Subject Index

A

- Academic degrees. *See* Degrees.
- Academic exchange visas issued to foreign countries, 98, 285
- Academic research. *See also* Applied research; Basic research; Development; Industrial research; Research and development.
- cross-institution collaboration in, 84, 264
- cross-sector interactions in
- cross-sector co-authorships and citations, 17, 95-96, 277-279
 - cross-sector mobility, 94-95, 272, 275-276
 - university-industry contacts, 96-98, 279-282
- equipment spending for, 14, 82-84, 256, 259-269
- facilities spending for, 14, 80-82, 256-258
- funding for, 13-14, 78-80, 241, 243-246, 253-254
- highlights of, 88
- institutions involved in, 89, 90, 241, 266-267
- international contacts in, 98
- case study in international collaboration, 99-100, 285-286, 291
 - cross-national attention, 12-13, 99, 289-290
 - DSDP, 99-100, 291
 - international collaboration, 98-100, 285-286, 291
 - publications, 99, 287-288
 - young researchers, 98, 271, 283-284
- overview of, 12-13, 17
- proposal activity and, 78-79
- S/E's in, 89-90
- employment sectors, 91-93, 268
 - growth patterns by field, 93-94, 273-274
 - minorities, 8, 91-92, 229-232, 270
 - number of, 90-91, 219-220, 268-269
 - postdoctoral positions, 92, 271
 - retention rates in research centers, 92, 292
 - women, 91, 270
- Accountants, salaries of, 179
- Administrators, salaries of, 179
- Aeronautical engineering
- doctoral research S/E's in, 90-91, 93-94, 269, 274
 - doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 - R&D funding in, 13-14, 79-80, 253-254
 - research S/E's in, 90-91, 93-94, 268, 273
 - S/E's employed in, 6-7, 64-66, 216, 218, 219, 225
- Affiliated firms, defined, 125*n*
- Africa, foreign students in U.S. from, 44, 201
- Agricultural sciences
- baccalaureate sources of doctorates in, 47-48, 207
 - graduate students, financial support for, 45-47, 205-206, 215
- as a probable major for freshmen, 25, 26, 179
- U.S. doctoral recipients studying abroad in, 98, 284
- Agriculture, Department of
- research data collections of, 85
 - S/E's employed in, 58
 - support of R&D by, 78, 79, 245, 249
- Alaskan Natives
- graduate students, enrollment of, 43

- precollege teachers in science and mathematics, 26, 181
- American Association of Engineering Societies, 41
- American Indians. *See* Native Americans.
- Applied research. *See also* Academic research; Basic research; Development; Industrial research; Research and development.
- academic doctoral S/E's in, 48-49, 213
 - funding for, 4-5, 13, 77-78, 240-242, 265
- Architecture
- as an intended major of precollege students, 24-25, 177
 - and SAT scores, 22-23, 175
- Articles
- cross-national citations in, 12-13, 99, 289-290
 - cross-sectoral institutional co-authorship of, 17, 95-96, 277-279
 - institutional co-authorship of, 84, 264, 279
 - international co-authorship of, 98-99, 285-286
 - U.S. and world publication of, 99, 287-288
- Arts
- as an intended major of precollege students, 24-25, 177
 - as a probable major for freshmen, 25, 26, 179
- Asian Americans
- doctoral research S/E's, 91-92, 270
 - doctorate recipients, 48, 209
 - graduate students, enrollment of, 43-44, 196, 197
 - precollege students
 - SAT scores of, 22-25, 175, 176, 178
 - years of mathematics, physical sciences, and biological sciences studies, 23
- precollege teachers in science and mathematics, 26, 181
- S/E's, employment of, 8, 63-64, 230-231
- Assistant and Associate Professors in S/E, 48, 214
- Astronautical engineering
- doctoral research S/E's in, 90-91, 93-94, 269, 274
 - doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 - R&D funding in, 13-14, 79-80, 253-254
 - research S/E's in, 90-91, 93-94, 268-273
 - S/E's employed in, 6-7, 64-66, 216, 218, 219, 225
- Attitudes
- of precollege students toward mathematics, 36, 193-194
 - public, toward S/T. *See* Public attitudes toward science and technology.
- Australia, public perceptions of benefits and harms from science, 18, 147-148, 332

B

- Bachelor's degrees. *See* Degrees, bachelor's.
- Balance of trade, 15, 124, 124*n*, 133, 314
- Basic research. *See also* Academic research; Applied research; Development; Industrial research; Research and development.
- academic doctoral S/E's in, 48-49, 213
 - cross-sector interactions in
 - cross-sector co-authorship and citations, 17, 95-96, 277-279

- cross-sector mobility, 94-95, 272, 275-276
 - university-industry contacts, 96-98, 280-281
- funding for, 4-5, 13, 77-79, 158, 159, 240-241, 247-252, 255, 265, 337
- highlights of, 88
- institutions involved in, 89, 90, 241, 266-267
- international contacts in, 98
- case study in international collaboration, 99-100, 291
 - cross-national attention, 12-13, 99, 289-290
 - DSDP, 99-100, 291
 - international collaboration, 98-100, 285-286, 291
 - publications, 99, 287-288
 - young researchers, 98, 271, 283-284
- overview of, 12-13, 17
- S/E's in, 89-90
- employment sectors, 91-93, 268
 - growth patterns by field, 93-94, 273-274
 - minorities, 8, 91-92, 230-232, 270
 - number of, 90-91, 218, 268-269
 - postdoctoral positions, 92, 271
 - retention rates in research centers, 92, 292
 - women, 91, 270
- Belgium
- precollege mathematics achievement scores in, 9, 24, 33-35, 177, 192
 - precollege mathematics courses taught in, 33-35, 191
 - public perceptions of benefits and harms from science, 18, 147-148, 331
 - weaving equipment innovations in, 118-119
- Biological sciences
- baccalaureate sources of doctorates in, 47-48, 207, 208
 - graduate students, financial support for, 45-47, 205, 206, 215
 - precollege years studied, 23-24
 - as a probable major for freshmen, 25, 26, 179
- Biology
- articles institutionally co-authored in, 84, 264, 279
 - articles internationally co-authored in, 98-99, 285
 - citations in articles in, 12-13, 99, 289-290
 - courses taken by precollege teachers in, 26-27, 181
 - faculty consultants to businesses in, 97, 281
 - research materials in, 85
 - U.S. and world articles in, 99, 287-288
- Biomedicine
- articles institutionally co-authored in, 84, 264, 279
 - articles internationally co-authored in, 98-99, 285
 - citations in articles in, 12-13, 99, 289-290
 - U.S. and world articles in, 99, 287-288
- Biosciences, U.S. doctoral recipients studying abroad in, 98, 284
- Biotechnology, 85, 115-116, 309-311
- Black Americans
- doctoral research S/E's, 91-92, 270
 - doctorate recipients, 48, 209
 - graduate students, enrollment of, 43-44, 196, 197
 - population of 18-21 year olds, in U.S., 195

precollege students
 computer competence of, 21-22
 mathematics achievement scores, 9, 21, 174
 SAT scores of, 22-25, 175, 176, 178
 science achievement scores, 9-10, 21, 174
 years of mathematics, physical sciences, and biological sciences studies, 23
 precollege teachers in science and mathematics, 26, 181
 S/E's, employment of, 8, 63-64, 230-231
 undergraduate students, enrollment of 18-21 year olds, 10, 41, 195
 Bureau of Labor Statistics (BLS), 67
 Bureau of the Census's Current Population Survey (CPS), 41*n*
 Business
 cross-sector mobility involving, 94-95, 272, 275-276
 doctoral research S/E's in, 90-93, 270
 as an intended major of precollege students, 24-25, 177
 minority doctoral research S/E's in, 91-92, 270
 as a probable major for freshmen, 25, 26, 179
 research S/E's in, 90-93, 268-269
 SBA classification of, 111, 111*n*
 S/E labor force trends in, 55-58, 219-221
 small. *See* Small business in high technology.
 women doctoral research S/E's in, 91, 270

C

CAD/CAM (computer-aided manufacturing / computer-aided design), 67
 "Cambridge phenomenon," 97-98
 Canada
 direct investment in the U.S. by, 128-130, 319
 internationally co-authored articles in, 98-99, 286
 patent citations from U.S. patents to earlier patents issued to, 110
 precollege mathematics achievement scores in, 9, 24, 33-35, 177, 192
 precollege mathematics courses taught in, 33-35, 191
 public perceptions of benefits and harms from science, 18, 147-148, 332
 royalty receipts from and payments to U.S., 130-132, 320-321
 sharing of DSDP costs by, 100
 U.S. direct investment in, 125-126, 135-136, 315, 318, 327
 U.S. patent application success rates for, 110-111, 306
 U.S. patents granted to inventors in, 109-110, 304
 Carnegie classification of institutions, 47, 47*n*, 209, 210, 210*n*, 211
 Carnegie Forum, 31
 Carnegie units, 32, 189
 Certification of precollege teachers, 31, 188
 Challenger accident, public reaction to, 141, 162-163, 340
 Chemical engineering
 doctoral research S/E's in, 90-91, 93-94, 269, 274
 doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 R&D funding in, 13-14, 79-80, 253-254
 research S/E's in, 90-91, 93-94, 268, 273
 S/E's employed in, 6-7, 64-66, 216, 218, 219, 225

Chemical technologies, innovations in, 117-118
 Chemistry
 articles institutionally co-authored in, 84, 264, 279
 articles internationally co-authored in, 98-99, 285
 baccalaureate sources of doctorates in, 47-48, 207
 citations in articles in, 12-13, 99, 289-290
 courses taken by precollege teachers in, 26-27, 181-183
 foreign recipients of U.S. doctoral degrees in, 92, 271, 283
 U.S. and world articles in, 99, 287-288
 U.S. doctoral recipients studying abroad in, 98, 284
 Chernobyl nuclear accident, public reaction to, 141, 162, 164-165
 Civil engineering
 doctoral research S/E's in, 90-91, 93-94, 269, 274
 doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 R&D funding in, 13-14, 79-80, 253-254
 research S/E's in, 90-91, 93-94, 268, 273
 S/E's employed in, 6-7, 64-66, 216, 218, 219, 225
 Clerical workers, salaries of, 180
 Clinical medicine
 articles institutionally co-authored in, 84, 264, 279
 articles internationally co-authored in, 98-99, 285
 citations in articles in, 12-13, 99, 289-290
 U.S. and world articles in, 99, 287-288
 Collaboration
 cross-institution, 84, 264
 cross-sector, 17, 95-96, 277-279
 international, 98-100, 285-286, 291, 292
 Collections of research materials, 85-86
 College degrees. *See* Degrees.
 College Placement Council, 67
 College students. *See* Students, graduate and undergraduate.
 Colleges and universities. *See also* Academic research.
 article cross-sector co-authorship and citations, 17, 95-96, 277-279
 Carnegie classification of, 47, 47*n*, 209, 210, 210*n*, 211
 consulting by faculty of, 97, 281
 cross-sector mobility involving, 94-95, 272, 275-276
 doctoral research S/E's in, 90-93, 269
 doctoral S/E's employed by, 48-49, 212-214
 enrollments in
 graduate, 41-44, 196-201
 undergraduate, 10, 41, 42, 195
 entrepreneurship in, 97-98, 282
 involvement in research, 89, 90, 241, 266-267
 minority doctoral research S/E's in, 91-92, 270
 participation in internationally co-authored articles, 98-99, 286
 patent activity in, 97, 108, 282
 postdoctorates in, 43, 200
 producers of S/E doctorates, 47-48, 207-211
 research S/E's in, 90-93, 268
 S/E labor force trends in, 55, 58, 219-220
 women doctoral research S/E's in, 91, 270
 Commerce, Department of, DOC-3 classification of industries, 111, 111*n*, 124, 127, 127*n*
 Competency tests, 32, 190

Computer-aided design/computer-aided manufacturing (CAD/CAM), 67
 Computer competence of precollege students, 21-22
 Computer science
 academic doctoral employment in, 48-49, 212-214
 baccalaureate sources of doctorates in, 47-48, 207
 courses taken by precollege teachers in, 26-27, 181-184
 doctoral research S/E's in, 90-91, 93-94, 269, 274
 doctorates awarded in, 44-45, 202
 faculty consultants to businesses in, 97, 281
 foreign recipients of U.S. doctoral degrees in, 92, 271, 283
 graduate S/E enrollment in, 41-44, 196-200
 graduate students, financial support for, 45-47, 205, 206, 215
 as an intended major of precollege students, 24-25, 177
 postdoctorates in doctoral-granting institutions, 43, 200
 as a probable major for freshmen, 25, 26, 179
 R&D funding in, 13-14, 79-80, 252-254
 research S/E's in, 90-91, 268
 and SAT scores, 22-23, 175
 Computer specialties
 doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 research S/E's in, 93-94, 273
 S/E's employed in, 6-8, 64-66, 216, 218, 219, 225
 Computers, public use of, 146-147, 331
 Concordance computer program (Patent Office), 109*n*
 Consulting
 academic doctoral S/E's in, 48-49, 213
 by faculty, 97, 281
 Cooperative Institutional Research Program, 41
 CPS (Current Population Survey), 41*n*
 Craft workers, salaries of, 180
 Cross-institution collaboration, 84, 264
 Cross-sector collaboration, 17, 95-96, 277-279
 Cross-sector mobility in research, 94-95, 272, 275-276
 Current Population Survey (CPS), 41*n*
 Czechoslovakia, weaving equipment innovations in, 118-119

D

Deep Sea Drilling Project (DSDP), 99-100, 291
 Defense, Department of
 S/E's employed in, 58
 support of R&D by, 78-80, 245, 248-249, 251
 support of S/E graduate students by, 46-47, 215
 Defense research and development (R&D), funding for, 3-5, 77, 265
 Deflator (GNP), 124*n*
 Degrees
 bachelor's, 11, 45, 203
 as first S/E degree, 5, 71, 233
 and the S/E workforce, 59-60, 222
 doctoral
 baccalaureate sources of, 47-48, 207-211
 foreign recipients of, 98, 271, 283
 by gender, 45, 203-204
 and the S/E workforce, 55, 56, 60-61, 220, 223-224
 summary of, 11-12, 44-45
 time from bachelor's degree, 45, 204
 from U.S. universities, 202

- master's, 11, 45, 203
 as first S/E degree, 5, 71, 233
 and the S/E workforce, 59-60, 222
- Demand**
 for precollege teachers, 27-29, 186
 for S/E's
 long-term, 67-68
 short-term, 67
- Demographic trends in the S/E labor force**
 bachelor's and master's degrees, 59-60, 222
 doctoral degrees, 60-61, 223-224
- Denmark, public perceptions of benefits and harms from science, 18, 147-148, 332**
- Development. *See also* Academic research; Applied research; Basic research; Industrial Research; Research and development.**
 academic doctoral S/E's in, 48-49, 213
 funding for, 4-5, 13, 77-78, 240-241, 265
 perceived expectations of, 148-150, 333-334
- Direct Investment Industry Class (DIIC), 127, 127*n***
- Division of Social and Economic Sciences (NSF), 86**
- DOC. *See* Commerce, Department of.**
- DOC-3 classification of industries, 111, 111*n*, 124, 127, 127*n***
- Doctoral degrees. *See* Degrees, doctoral.**
- DoD. *See* Defense, Department of.**
- DOE (Department of Energy), 32**
- DSDP (Deep Sea Drilling Project), 99-100, 291**
- E**
- Earth sciences**
 articles institutionally co-authored in, 84, 264, 279
 articles internationally co-authored in, 98-99, 285
 baccalaureate sources of doctorates in, 47-48, 207
 citations in articles in, 12-13, 99, 289-290
 courses taken by precollege teachers in, 26-27, 181-183
 foreign recipients of U.S. doctoral degrees in, 92, 271, 283
 as an intended major of precollege students, 24-25, 177
 research materials in, 85
 and SAT scores, 22-23, 175
 U.S. and world articles in, 99, 287-288
 U.S. doctoral recipients studying abroad in, 98, 284
- East Asia**
 exports and imports of high-technology products, 133-135, 326
 foreign students in U.S. from, 44, 201
 NIC's in, 134-135, 326
- East Europe, U.S. academic exchange visas issued to, 98, 285**
- Economic Recovery Tax Act, 105**
- Economics**
 baccalaureate sources of doctorates in, 47-48, 207
 research materials in, 86
- Education**
 courses taken by precollege teachers in, 26-27, 181, 183, 184
 graduate
 enrollment in, 41-44, 196-200
 foreign students in, 12, 44, 45, 196, 198, 201
 highlights of, 40
 overview of, 10-12
 time from bachelor's to doctoral degree, 45, 204
- as an intended major of precollege students, 24-25, 177
- precollege**
 computer competence, 21-22
 highlights of, 20
 intended majors of students, 24-25, 177
 mathematics achievement scores, 9, 21, 24, 33-35, 174, 177, 192
 mathematics courses taught, 33-35, 191
 mathematics textbook content, 35-36, 193
 overview of, 9-10
 SAT scores, 22-25, 175-178
 science achievement scores, 9-10, 21, 174
 students' attitudes toward mathematics, 36, 193-194
- as a probable major for freshmen, 25, 26, 179
- in S/E, public attitudes toward, 143-145
- undergraduate**
 enrollment in, 10, 41, 42, 195
 expected majors of freshmen, 25, 26, 179
 foreign students in, 44, 201
 highest degree planned by freshmen, 11, 41, 42
 highlights of, 40
 overview of, 10-12
 probable career occupation of freshmen, 10, 11, 41
 probable majors of freshmen, 10, 11, 41, 42
- Educational institutions. *See* Colleges and universities.**
- Electrical/electronics engineering**
 doctoral research S/E's in, 90-91, 93-94, 269, 274
 doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 R&D funding in, 13-14, 79-80, 253-254
 research S/E's in, 90-91, 93-94, 268, 273
 S/E's employed in, 6-7, 64-66, 216, 218, 219, 225
- Elementary students. *See* Students, precollege**
- Employment**
 perceived effect of S/T on, 150-152
 rates of, in S/E, 64, 225
- Energy, Department of (DOE), 32**
 support of R&D by, 78-80, 245, 248-249, 251
- Engineering. *See also* Science; Science and engineering.**
 articles institutionally co-authored in, 84, 264, 279
 articles internationally co-authored in, 98-99, 285
 baccalaureate sources of doctorates in, 47-48, 207, 208, 211
 citations in articles in, 12-13, 99, 289-290
 doctorates awarded in, 44-45, 202
 foreign recipients of U.S. doctoral degrees in, 92, 271, 283
 graduate S/E enrollment in, 41-44, 196-200
 graduate students
 financial support for, 45-47, 205, 206, 215
 time from bachelor's to doctoral degree, 45, 204
 as an intended major of precollege students, 24-25, 177
 as a probable major for freshmen, 25, 26, 179
 R&D funding in, 13-14, 79-80, 253-255
 and SAT scores, 22-23, 175
 undergraduate enrollment in, 42
 U.S. and world articles in, 99, 287-288
 U.S. doctoral recipients studying abroad in, 98, 284
- Engineering Manpower Commission, 41**
- Engineering technology, undergraduate enrollment in, 42**
- Engineers. *See also* Scientists; Scientists and engineers.**
 academic doctoral employment of, 48-49, 212-214
 defined, 52*n*
 doctoral research S/E's, 90-91, 93-94, 269, 274
 doctoral S/E's, 55, 56, 60-61, 220, 223, 224
 employed S/E's, 6-8, 64-66, 216, 218, 219, 225
 faculty consultants to businesses, 97, 281
 postdoctorates in doctoral-granting institutions, 43, 200
 research S/E's, 90-91, 93-94, 268, 273
- England. *See* United Kingdom.**
- Enrollments**
 graduate, 41-44, 196-200
 public school, 27-28, 187
 undergraduate, 10, 41, 42, 195
- Entrepreneurship in colleges and universities, 97-98**
- Environmental engineering**
 as an intended major of precollege students, 24-25, 177
 and SAT scores, 22-23, 175
- Environmental sciences**
 academic doctoral employment in, 48-49, 212-214
 baccalaureate sources of doctorates in, 47-48, 208
 courses taken by precollege teachers in, 26-27, 181
 doctoral research S/E's in, 90-91, 93-94, 269, 274
 doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 faculty consultants to businesses in, 97, 281
 foreign recipients of U.S. doctoral degrees in, 92, 271
 graduate S/E enrollment in, 41-44, 196-200
 graduate students, financial support for, 45-47, 205, 206, 215
 as an intended major of precollege students, 24-25, 177
 postdoctorates in doctoral-granting institutions, 43, 200
 R&D funding in, 13-14, 79-80, 253-255
 research materials in, 85
 research S/E's in, 90-91, 93-94, 268, 273
 and SAT scores, 22-23, 175
 S/E's employed in, 6-8, 64-66, 216, 218, 219, 225
 U.S. doctoral recipients studying abroad in, 98, 284
- Equipment, R&D spending for, 14, 82-84, 256, 259-263**
- Ethnic comparisons**
 doctoral research S/E's, 91-92, 270
 doctorate recipients, 48, 209
 graduate students, enrollment of, 43-44, 196, 197
 population of 18-21 year olds, in U.S., 195
- precollege students**
 mathematics achievement scores, 9, 21, 174
 SAT scores of, 22-25, 175, 176, 178
 science achievement scores, 9-10, 21, 174
 years of mathematics, physical sciences, and biological sciences studies, 23
- precollege teachers in science and mathematics, 26, 181**
- S/E's, employment of, 8, 63-64, 230-232**
- undergraduate students, enrollment of 18-21 year olds, 10, 41, 195**
- Europe**

foreign students in U.S. from, 44, 201
royalty receipts from and payments to U.S., 130-132, 320-323
Exports. *See* International markets for U.S. technology.

F

Facilities
defined, 80*n*
R&D spending for, 14, 80-82, 256-258
Factory workers, salaries of, 180
Faculty, consulting by, 97, 281
Federal government
article cross-sector co-authorship and citations, 17, 95-96, 277-278
cross-sector mobility involving, 94-95, 272, 275
doctoral research S/E's in, 90-93, 269
funding for R&D by. *See* Research and development, funding for.
involvement in research, 89, 90, 241, 266-267
minority doctoral research S/E's in, 91-92, 270
participation in internationally co-authored articles, 98-99, 286
regulation of S/T by, 160-161
research S/E's in, 90-93, 268
S/E labor force trends in, 55, 58, 219-220
support of S/E graduate students by, 45-47, 205, 215
women doctoral research S/E's in, 91, 270
Federal Intramural Laboratories, R&D support of, 79, 249
Federal programs for precollege teachers, 31-32
Federal Republic of Germany (FRG). *See* West Germany.
Federally Funded Research and Development Centers (FFRDC's)
article cross-sector co-authorship and citations, 17, 95-96, 277-278
involvement in research, 89, 90, 241, 266-267
participation in internationally co-authored articles, 98-99, 286
R&D expenditures for, 14, 77, 79, 238-239, 241, 248
Financial support of S/E graduate students
by gender, 46-47, 215
introduced, 45-46
source of, 46-47, 205, 215
type of, 46, 206
Finland
precollege mathematics achievement scores in, 9, 24, 33-35, 177, 192
precollege mathematics courses taught in, 33-35, 191
Foreign college students
graduate, 12, 44, 45, 196, 198, 201
undergraduate, 44, 201
Foreign countries, data for. *See* International comparisons.
Foreign recipients of U.S. doctoral degrees, 92, 98, 271, 283
Forestry as a probable major for freshmen, 25, 26, 179
France
basic research performers in, 89, 90, 267
direct investment in the U.S. by, 128-130, 318
exports of high-technology products from, 133-135, 324-326
industrial R&D funding and performance in, 103, 293

internationally co-authored articles in, 98-99, 286
national R&D expenditures in, 3-4, 77, 234-237
patent citations from U.S. patents to earlier patents issued to, 110
precollege mathematics achievement scores in, 33-35, 192
precollege mathematics courses taught in, 33-35, 191
public attitudes on U.S. vs. foreign S/T, 157-159, 336-337
public perceptions of benefits and harms from science, 18, 147-149, 332
royalty receipts from and payments to U.S., 130-132, 320-321
S/E's employed in, 5, 70-72, 226-229
sharing of DSDP costs by, 100
U.S. academic exchange visas issued to, 98, 285
U.S. direct investment in, 125-126, 135-136, 315, 327
U.S. patent application success rates for, 110-111, 306
U.S. patents granted to inventors from, 107, 302
U.S. patents granted to inventors in, 109-110, 304-305
weaving equipment innovations in, 118-119
FRG (Federal Republic of Germany). *See* West Germany.
Funding for R&D. *See* Research and development, funding for.

G

Gender comparisons. *See also* Women.
doctoral research S/E's, 91, 270
doctorate recipients, 48, 209
graduate students
degrees awarded, 45, 203
enrollment of, 43, 200
financial support of, 46-47, 215
time from bachelor's to doctoral degree, 45, 204
population of 18-21 year olds, in U.S., 195
precollege students
computer competence of, 21-22
mathematics achievement scores, 9, 21, 174
SAT scores of, 22-25, 175, 176, 178
science achievement scores, 9-10, 21, 174
years of mathematics, physical sciences, and biological sciences studies, 23-24
precollege teachers, in science and mathematics, 26, 180
public acceptance of scientific conclusions, 335
public assessment of beneficial vs. harmful results of scientific research, 331
public assessment of genetic engineering research, 339
public assessment of nuclear power, 339
public assessment of space exploration, 338
public attentive to or interested in S/T, 328
public computer use, 331
public image of scientists, 335
public support for basic scientific research, 337
public understanding of various aspects of S/T, 328-329
public use of information sources, 330
public views of the limits of science, 336
S/E's
doctoral, 62-63, 220, 223-224

employment of, 7-8, 61-63, 70-72, 216, 220, 223-224, 226
undergraduate students
degrees awarded, 45, 203
enrollment of 18-21 year olds, 10, 41, 195
probable majors for freshmen, 25, 26, 179
Gene research libraries, 85
Germany. *See* West Germany.
Germplasm data, 85
GNP. *See* Gross National Product.
Grade Point Average (GPA), entry, for education majors, 31
Graduate students. *See* Students, graduate.
Great Britain. *See* United Kingdom.
Gross National Product (GNP)
implicit price deflator, 124*n*
R&D funding as a percent of, 3, 77, 236-238

H

Health and Human Services, Department of, support of S/E graduate students by, 47, 215
Health professions (non-MD)
as an intended major of precollege students, 24-25, 177
as a probable major for freshmen, 25, 26, 179
Health sciences
baccalaureate sources of doctorates in, 47-48, 207
graduate students, financial support for, 45-47, 205, 206, 215
Health workers (non-MD), salaries of, 180
HHS. *See* Health and Human Services, Department of.
Higher education. *See* Education, graduate and undergraduate.
Higher education research, 30, 31
Hispanic Americans
doctorate recipients, 48, 209
graduate students, enrollment of, 43-44, 196, 197
population of 18-21 year olds in U.S., 195
precollege students
computer competence of, 21-22
mathematics achievement scores, 9, 21, 174
SAT scores of, 22-25, 175, 176, 178
science achievement scores, 9-10, 21, 174
precollege teachers in science and mathematics, 26, 181
S/E's, employment of, 8, 63-64, 232
undergraduate students, enrollment of 18-21 year olds, 10, 41, 195
Holmes Group, 26
Hong Kong
exports and imports of high-technology products, 133-135, 326
precollege mathematics achievement scores in, 33-35, 192
Human resources. *See* Science and engineering, workforce in.
Humanities
graduate students, time from bachelor's to doctoral degree, 45, 204
as an intended major of precollege students, 24-25, 177
as a probable major for freshmen, 25, 26, 179
Hungary
precollege mathematics achievement scores in, 9, 24, 33-35, 177, 192
precollege mathematics courses taught in, 33-35, 191

- I**
- Imports. *See* International markets for U.S. technology.
- Income research data, 86
- Independent research and development (IR&D), 104*n*
- Indirect cost ratio (NIH), 78, 79, **246, 246*n***
- Industrial engineering
 research S/E's in, 90-91, 93-94, **268, 273**
 S/E's employed in, 6 **225**
- Industrial research. *See also* Academic research; Applied research; Basic research; Development; Research and development.
 funding for, 13, 77, 80, **241, 250-251, 255**
 highlights of, 102-103
 overview of, 12, 13, 16
 patented inventions, 106
 citations from patents to previous patents, 110
 inventors and owners of inventions patented in the U.S., 12, 13, 106-109, **303**
 patenting by individual countries in various fields, 109-110, **304-305**
 success rates of patent applications, 110-111, **306**
- R&D expenditures in industry, 16, 103, 104, **293-296**
 R&D expenditures and employment in individual industries, 16, 105-106, **295-301**
 trends in company funding, 104-105, **294**
 trends in Federal funding, 105
- S/E personnel in industry, 103-104, **218, 227**
- small business in high technology, 111
 and biotechnology, 115-116, **309-311**
 employment in, 111-114, **306**
 venture capital and, 114-115, **306-308**
- technological innovation in industry
 efforts across U.S. industry, 16, 116-117, **312**
 in individual technologies, 117-119
- Industry**
 article cross-sector co-authorship and citations, 17, 95-96, **277-279**
 cross-sector mobility involving, 94-95, **272, 275-276**
 DOC-3 classification of, 111, 111*n*, 124, 127, 127*n*
 doctoral research S/E's in, 90-93, **269**
 involvement in research, 89, 90, **241, 266-267**
 minority doctoral research S/E's in, 91-92, **270**
 participation in internationally co-authored articles, 98-99, **286**
 research S/E's in, 90-93, **268**
 S/E labor force trends in, 55-58, **219-221**
 women doctoral research S/E's in, 91, **270**
- Information in S/T, public consumption of, 145-146, **330**
- Initial Public Offerings (IPO's), 114-115, **308**
- Innovation. *See* Technological innovation in industry.
- Input-Output studies on precollege teachers, 33
- Institutional support. *See* Financial support.
- Institutions**
 educational. *See* Colleges and universities.
 nonprofit. *See* Nonprofit institutions.
- Instructors in S/E**, 48, **214**
- Instrumentation**
 defined, 82*n*
 R&D spending for, 14, 82-84, **256, 259-263**
- Interdisciplinary sciences**
 as an intended major of precollege students, 24-25, **177**
 and SAT scores, 22-23, **175**
- International Association for Social Sciences Information Services and technology, 86
- International collaboration, 98-100, **285-286, 291**
- International comparisons**
 articles internationally co-authored, 98-99, **285-286, 291**
 employment of S/E's, 70-72, **226-229**
 exports of high-technology products, 133-135, **324-326**
 first degrees in S/E, 5, 71, **233**
 foreign direct investment in the U.S., 128-130, **318**
 imports of high-technology products, 133-135, **324-326**
 industrial R&D funding and performance, 103, **293**
 national R&D expenditures, 3-4, 77, **234-238**
 patent citations from U.S. patents to earlier patents, 110
 performers of basic research, 89, 90, **267**
 precollege mathematics achievement scores, 9, 24, 33-35, **177, 192**
 precollege mathematics courses taught, 33-35, **191**
 public attitudes on U.S. vs. foreign S/T, 157-159, **336-337**
 public perceptions of benefits and harms from science, 18, 147-148, **332**
 supercomputer installations, 85
 technology sales and purchase agreements with Japan, 132, **322-323**
 U.S. academic exchange visas issued, 98, **285**
 U.S. direct investment in foreign countries, 125-126, 135-136, **315-317, 327**
 U.S. patent application success rates, 110-111, **306**
 U.S. patents granted to foreign inventors, 107, 109-110, **302, 304-305**
 U.S. receipts and payments of royalties, 130-132, **320-323**
 weaving equipment innovations, 118-119
- International markets for U.S. technology**
 highlights of, 122-123
 international diffusion of technology, 123
 foreign direct investment in the U.S., 128-130, **318-319**
 international direct investment, 125-128, **315-319**
 international trade in high-technology products, 15, 123-125, **313-314**
 patent licenses and technology agreements, 130-132, **322-323**
 overview of, 15
 technology and U.S. competitiveness, 133
 direct investment and firm competitiveness, 125-126, 135-136, **315-317, 327**
 high-technology trade competitiveness, 15, 133-135, **313, 324-326**
- IPO's (Initial Public Offerings)**, 114-115, **308**
- IR&D (Independent research and development)**, 104*n*
- Iran**, U.S. academic exchange visas issued to, 98, **285**
- Ireland**
 public perceptions of benefits and harms from science, 18, 147-148, **332**
 weaving equipment innovations in, 118-119
- Israel**
 precollege mathematics achievement scores in, 9, 24, 33-35, **177, 192**
 precollege mathematics courses taught in, 33-35, **191**
- Italy**
 patent citations from U.S. patents to earlier patents issued to, 110
 public perceptions of benefits and harms from science, 18, 147-148, **332**
 U.S. patent application success rates for, 110-111, **306**
 U.S. patents granted to inventors in, 109-110, **304**
 weaving equipment innovations in, 118-119
- J**
- Japan**
 basic research performers in, 89, 90, **267**
 direct investment in the U.S. by, 128-130, **318**
 exports and imports of high-technology products, 133-135, **324-326**
 industrial R&D funding and performance in, 103, **293**
 internationally co-authored articles in, 98-99, **286**
 national R&D expenditures in, 3-4, 77, **234-237**
 patent citations from U.S. patents to earlier patents issued to, 110
 precollege mathematics achievement scores in, 9, 24, 33-35, **177, 192**
 precollege mathematics courses taught in, 33-35, **191**
 public attitudes on U.S. vs. foreign S/T, 157-159, **336-337**
 public perceptions of benefits and harms from science, 18, 147-149, **332**
 royalty receipts from and payments to U.S., 130-132, **320-323**
 S/E's employed in, 5, 70-72, **226-229**
 sharing of DSDP costs by, 100
 supercomputer installations in, 85
 technology sales and purchase agreements with, 132, **322-323**
 U.S. academic exchange visas issued to, 98, **285**
 U.S. direct investment in, 125-126, 135-136, **315, 327**
 U.S. patent application success rates for, 110-111, **306**
 U.S. patents granted to inventors from, 107, **302**
 U.S. patents granted to inventors in, 109-110, **304-305**
 weaving equipment innovations in, 118-119
- K**
- Korea.** *See* South Korea.
- Kuwait**, public perceptions of benefits and harms from science, 18, 147-148, **332**
- L**
- Labor force in S/E.** *See* Science and engineering, workforce in.
- Land Grant College system**, 20
- Language arts**, Carnegie units required in, 32, **189**
- Latin America**, foreign students in U.S. from, 44, **201**
- Lawrence Berkeley Laboratory (LBL)**, 32

Lawrence Livermore National Laboratory, 85
 Lebanon, public perceptions of benefits and
 harms from science, 18, 147-148, 332
 Life sciences
 academic doctoral employment in, 48-49,
 212-214
 baccalaureate sources of doctorates in,
 47-48, 207, 211
 courses taken by precollege teachers in,
 26-27, 181-183
 doctoral research S/E's in, 90-91, 93-94, 269,
 274
 doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 doctorates awarded in, 44-45, 202
 foreign recipients of U.S. doctoral degrees
 in, 92, 271, 283
 graduate S/E enrollment in, 41-44, 196-200
 graduate students
 financial support for, 45-47, 215
 time from bachelor's to doctoral degree,
 45, 204
 as an intended major of precollege stu-
 dents, 24-25, 177
 postdoctorates in doctoral-granting institu-
 tions, 43, 200
 R&D funding in, 13-14, 79-80, 252-255
 research S/E's in, 90-91, 93-94, 268, 273
 and SAT scores, 22-23, 175
 S/E's employed in, 6-8, 64-66, 216, 218, 219,
 225
 Literature. *See* Articles.
 Los Alamos National Laboratory, 85
 Luxembourg
 precollege mathematics achievement scores
 in, 33-35, 192
 precollege mathematics courses taught in,
 33-35, 191

M

Management of R&D, academic doctoral S/E's
 in, 48-49, 213
 Managers, salaries of, 180
 Markets, international. *See* International mar-
 kets for U.S. technology.
 Master's degrees. *See* Degrees, master's.
 Materials engineering
 doctoral research S/E's in, 90-91, 93-94, 269,
 274
 doctoral S/E's in, 220, 224
 research S/E's in, 90-91, 93-94, 268, 273
 S/E's employed in, 6-225
 Mathematical sciences
 academic doctoral employment in, 48-49,
 212-214
 doctoral research S/E's in, 90-91, 93-94, 269,
 274
 doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 foreign recipients of U.S. doctoral degrees
 in, 92, 271, 283
 research S/E's in, 90-91, 93-94, 269, 273
 S/E's employed in, 6-8, 64-66, 216, 218, 219,
 225
 Mathematics
 articles institutionally co-authored in, 84,
 264
 articles internationally co-authored in,
 98-99, 285
 baccalaureate sources of doctorates in,
 47-48, 207
 Carnegie units required in, 32, 189
 citations in articles in, 12-13, 99, 289-290
 courses taken by precollege teachers in,
 26-27, 182-185
 doctorates awarded in, 44-45, 202
 faculty consultants to businesses in, 97, 281

graduate S/E enrollment in, 41-44, 196-200
 graduate students, financial support for,
 45-47, 205, 206, 215
 as an intended major of precollege stu-
 dents, 24-25, 177
 NSF programs to improve learning and
 teaching in, 32
 postdoctorates in doctoral-granting institu-
 tions, 43, 200
 precollege
 achievement scores in, 9, 21, 24, 33-35,
 174, 177, 192
 courses taught in, 33-35, 191
 highlights of, 20
 overview of, 9-10
 SAT scores in, 22-25, 175-178
 students' attitudes toward, 36, 193-194
 textbook content for, 35-36, 193
 years studied, 23-24
 as a probable major for freshmen, 25, 26,
 179
 R&D funding in, 13-14, 79-80, 252-255
 U.S. and world articles in, 99, 287-288
 U.S. doctoral recipients studying abroad in,
 98, 284
 Mechanical engineering
 doctoral research S/E's in, 90-91, 93-94, 269,
 274
 doctoral S/E's in, 55, 56, 60-61, 220, 223, 224
 R&D funding in, 13-14, 79-80, 253-254
 research S/E's in, 90-91, 93-94, 268, 273
 S/E's employed in, 6-7, 64-66, 216, 218, 219,
 225
 Merger, defined, 112*n*
 Meteorological research data, 85
 Mexican Americans, precollege students
 SAT scores of, 22-25, 175, 176, 178
 years of mathematics, physical sciences,
 and biological sciences studies, 23
 Middle East, foreign students in U.S. from,
 44, 201
 Minimum competency tests, 32, 190
 Mining engineering
 research S/E's in, 90-91, 93-94, 268, 273
 S/E's employed in, 6, 225
 Minorities in the S/E workforce, 8, 63-64,
 230-232
 Minority comparisons. *See* Ethnic
 comparisons.
 Molecular-beam epitaxy, research in, 96

N

NAEP (National Assessment of Educational
 Progress), 9, 21-22
 NASA. *See* National Aeronautics and Space
 Administration.
 National Academy of Sciences report sum-
 marizing research on teachers, 33
 National Aeronautics and Space Administra-
 tion (NASA), support of R&D by, 78-80,
 245, 248-249, 251
 National Assessment of Educational Progress
 (NAEP), 9, 21-22
 National Board for Professional Teaching
 Standards, 26
 National Board of Professional Standards, 31
 National Council of Teachers of Mathematics
 (NCTM), 27
 National Election Studies and General Social
 Survey, 86
 National Environmental Satellite, Data, and
 Information Service, 85
 National Governor's Association, 97
 National Institutes of Health (NIH)
 indirect cost ratio, 78, 79, 246, 246*n*

research data collections of, 85
 support of graduate students by, 47, 215
 support of R&D by, 78-80, 245, 248-249, 251
 National Plant Germplasm System, 85
 National Research Council analysis of pro-
 ducers of S/E doctorates, 47-48
 National Science Foundation (NSF)
 Division of Social and Economic Sciences,
 86
 ocean drilling program of, 99-100
 programs to improve science and mathe-
 matics teaching and learning, 32
 support of R&D by, 78-80, 245, 248-249, 251
 support of S/E graduate students by, 47, 215
 National Science Teachers Association
 (NSTA), 26, 29
 Native Americans
 doctorate recipients, 48, 209
 graduate students, enrollment of, 43
 precollege students
 SAT scores of, 22-25, 175, 176, 178
 years of mathematics, physical sciences,
 and biological sciences studies, 23
 precollege teachers in science and mathe-
 matics, 26, 181
 NCTM (National Council of Teachers of Mathe-
 matics), 27
 Netherlands
 direct investment in the U.S. by, 128-130,
 318
 patent citations from U.S. patents to earlier
 patents issued to, 110
 precollege mathematics achievement scores
 in, 33-35, 192
 precollege mathematics courses taught in,
 33-35, 191
 public perceptions of benefits and harms
 from science, 18, 147-148, 332
 U.S. direct investment in, 125-126, 135-136,
 327
 U.S. patent application success rates for,
 110-111, 306
 Netherlands Antilles
 direct investment in the U.S. by, 128-130,
 318
 investing firms incorporated in, 128*n*
 New Zealand
 precollege mathematics achievement scores
 in, 9, 24, 33-35, 177, 192
 precollege mathematics courses taught in,
 33-35, 191
 Newly Industrialized Countries (NIC's),
 134-135, 326
 Newspapers, science and health sections in,
 146, 330
 Nigeria
 precollege mathematics achievement scores
 in, 33-35, 192
 precollege mathematics courses taught in,
 33-35, 191
 NIH. *See* National Institutes of Health.
 Nonacademic applied research. *See* Applied
 research.
 Nonacademic basic research. *See* Basic
 research.
 Non-defense research and development
 (R&D), funding for, 3-5, 77, 236-237, 265
 Nonprofit institutions
 article cross-sector co-authorship and cita-
 tions, 17, 95-96, 277-279
 cross-sector mobility involving, 94-95, 272
 doctoral research S/E's in, 90-93, 269
 involvement in research, 89, 90, 241,
 266-267
 minority doctoral research S/E's in, 91-92,
 270

participation in internationally co-authored articles, 98-99, **286**
 R&D support of, 77, **238-239**
 research S/E's in, 90-93, **268**
 women doctoral research S/E's in, 91, **270**
 North America, foreign students in U.S. from, 44, **201**
 NSF. *See* National Science Foundation.
 NSTA (National Science Teachers Association), 26, 29
 Nuclear accidents, public reaction to Chernobyl, 141, 162, 164-165
 Three Mile Island, 164
 Nuclear engineering
 doctoral research S/E's in, 90-91, 93-94, **269, 274**
 doctoral S/E's in, 55, 56, 60-61, **220, 223, 224**
 research S/E's in, 90-91, 93-94, **268-273**
 S/E's employed in, 6, **225**
 Nuclear power, public attitudes toward, 164-165, **338**

O

Oceania, foreign students in U.S. from, 44, **201**
 Office of Technology Assessment, 97
 Organisation for Economic Co-operation and Development (OECD), 133, 136

P

Pacific Islanders
 graduate students, enrollment of, 43
 precollege teachers in science and mathematics, 26, **181**
 Panel Study of Income Dynamics, 86
 Participation rates in the S/E labor force, 64, **225**
 Patents, 106
 activity in colleges and universities, 97, **282**
 citations from patents to previous patents, 110
 granted to colleges and universities, 97, **108, 282**
 highlights of, 102
 inventors and owners of inventions patented in the U.S., 12, 13, 106-109, **302-303**
 overview of, 12, 13
 patent licenses and technology agreements, 130-132, **320-323**
 patenting by individual countries in various fields, 109-110, **304-305**
 success rates of patent applications, 110-111, **306**
 Uniform Federal Patent Policy Act, 108
 Petroleum engineering
 research S/E's in, 90-91, 93-94, **268, 273**
 S/E's employed in, 6, **225**
 Ph.D. degrees. *See* Degrees, doctoral.
 Physical sciences
 academic doctoral employment in, 48-49, **212-214**
 baccalaureate sources of doctorates in, 47-48, **207, 208, 211**
 doctoral research S/E's in, 90-91, 93-94, **269, 274**
 doctoral S/E's in, 55, 56, 60-61, **220, 223, 224**
 doctorates awarded in, 44-45, **202**
 faculty consultants to businesses in, 97, **281**
 foreign recipients of U.S. doctoral degrees in, 92, **271, 283**
 graduate S/E enrollment in, 41-44, **196-200**
 graduate students
 financial support for, 45-47, **205, 206, 215**

 time from bachelor's to doctoral degree, 45, **204**
 as an intended major of precollege students, 24-25, **177**
 postdoctorates in doctoral-granting institutions, 43, **200**
 precollege years studied, 23-24
 as a probable major for freshmen, 25, 26, **179**
 R&D funding in, 13-14, 79-80, **252-255**
 research S/E's in, 90-91, 93-94, **268, 273**
 and SAT scores, 22-23, **175**
 S/E's employed in, 6-8, 64-66, **216, 218, 219, 225**
 Physics
 articles institutionally co-authored in, 84, **264**
 articles internationally co-authored in, 98-99, **285**
 citations in articles in, 12-13, 99, **289-290**
 courses taken by precollege teachers in, 26-27, **181-183**
 foreign recipients of U.S. doctoral degrees in, 92, **271, 283**
 U.S. and world articles in, 99, **287-288**
 U.S. doctoral recipients studying abroad in, 98, **284**
 Plant, R&D spending for, 14, 80-82, **256-258**
 Poland, U.S. academic exchange visas issued to, 98, **285**
 Policy areas, public attitudes toward
 advantages vs. disadvantages of various technologies, 161-162, **338-339**
 funding for basic research, 158, 159, **337**
 government regulation of S/T, 160-161
 restriction of research, 158-160, **338**
 Political research data, 86
 Population, U.S.
 18-21 year olds, **195**
 18-24 and 25-34 year olds, **226**
 Postdoctorates
 in doctorate-granting institutions, 43, **200**
 in research, 92, **271**
 Precollege education. *See* Education, precollege.
 Precollege students. *See* Students, precollege.
 Precollege teachers. *See* Teachers, precollege.
 Pre-dentistry as a probable major for freshmen, 25, 26, **179**
 Pre-law as an intended major of precollege students, 24-25, **177**
 Pre-medicine
 as an intended major of precollege students, 24-25, **177**
 as a probable major for freshmen, 25, 26, **179**
 Pre-veterinary science as a probable major for freshmen, 25, 26, **179**
 Primary education. *See* Education, precollege.
 Primary mathematics. *See* Mathematics, precollege.
 Primary science. *See* Science, precollege.
 Primary teachers. *See* Teachers, precollege.
 Private industry. *See* Industry.
 Private sector programs for precollege teachers, 31-32
 Process-Product studies on precollege teachers, 33
 Professional fields, time from bachelor's to doctoral degree, 45, **204**
 Professionals, salaries of, **180**
 Professors in S/E, 48, **214**
 Proposal activity and academic R&D, 78-79
 Psychology
 academic doctoral employment in, 48-49, **212-214**

 baccalaureate sources of doctorates in, 47-48, **207**
 doctoral research S/E's in, 90-91, 93-94, **269, 274**
 doctoral S/E's in, 55, 56, 60-61, **220, 223, 224**
 doctorates awarded in, 44-45, **202**
 foreign recipients of U.S. doctoral degrees in, 92, **271, 283**
 graduate S/E enrollment in, 41-44, **196-200**
 graduate students, financial support for, 45-47, **205, 206, 215**
 as an intended major of precollege students, 24-25, **177**
 postdoctorates in doctoral-granting institutions, 43, **200**
 R&D funding in, 13-14, 79-80, **252-254**
 research S/E's in, 90-91, 93-94, **268, 273**
 and SAT scores, 22-23, **175**
 S/E's employed in, 6-8, 64-66, **216, 218, 219, 225**
 U.S. doctoral recipients studying abroad in, 98, **284**
 Public attitudes toward science and technology (S/T)
 highlights of, 140-142
 knowledge, interest, and attitudes regarding S/T, 142
 attentiveness to S/T, 142-143, **328**
 attitudes toward S/E education, 143-145
 knowledge of S/T terms, 143-144, **328-329**
 overview of, 18
 perceived results of S/T, 147
 benefits vs. harms from scientific research, 18, 147-149, **331-332**
 effect of S/T on work and employment, 150-152
 expectation of future S/T developments, 148-150, **333-334**
 personal activities involving S/T, 145
 consumption of information, 145-146, **330**
 use of computers, 146-147, **331**
 public acceptance of S/T, 152
 acceptance of scientific thinking, 153-156, **335**
 attitudes toward scientists, 152-153, **334-335**
 limits and alternatives to scientific thinking, 155-156, **336**
 U.S. vs. foreign S/T, 157-159, **336-337**
 reactions to Challenge and Chernobyl accidents, 141, 162, 164-165
 attitudes toward nuclear power, 164-165, **339**
 attitudes toward space program and S/T generally, 163-164, **338**
 reactions to space shuttle accident, 141, 162-163, **340**
 S/T policy areas
 advantages vs. disadvantages of various technologies, 161-162, **338-339**
 funding for basic research, 158, 159, **337**
 government regulation of S/T, 160-161
 restriction of research, 158-160, **338**
 Public school education. *See* Education, precollege.
 Public school enrollments, 27-28, **187**
 Public school students. *See* Students, precollege.
 Public school teachers. *See* Teachers, precollege.
 Publications. *See* Articles.
 Puerto Ricans, precollege students
 SAT scores of, 22-25, **175, 176, 178**
 years of mathematics, physical sciences, and biological sciences studies, 23

R

- R&D. *See* Research and development.
- Racial comparisons. *See* Ethnic comparisons.
- Reforms
- federal and private sector programs for, 31-32
 - by higher education, 30, 31
 - for precollege students, 32
 - for precollege teachers, 29-31
- Regulation of S/T, 160-161
- Republic of Korea. *See* South Korea.
- Research. *See also* Academic research; Applied research; Basic research; Development; Industrial research; Research and development.
- cross-sector mobility in, 94-95, 272, 275-276
 - international contacts in. *See* Basic research, international contacts in.
 - perceived benefits vs. harms from, 18, 147-149, 331-332
 - postdoctorates in, 92, 272
 - on precollege teachers and teaching, 32-33
 - restriction of, 158-160, 338
 - retention rates in, 92, 292
 - sectoral trends in. *See* Sectoral trends, in research.
 - in silicon molecular-beam epitaxy, 96
 - in transition-metal silicides, 96
- Research and development (R&D). *See also* Academic research; Applied research; Basic research; Development; Industrial research.
- defense, 3-5, 77, 265
 - funding for
 - character of work, 4-5, 13, 77-78, 240-241, 265
 - highlights of, 76
 - international comparisons, 3-4, 77, 234-238
 - overview of, 3-5, 13-14, 17
 - as a percent of GNP, 3, 77, 236-238
 - performers, 77, 239-240
 - sources of, 4, 77, 234-235
- IR&D, 104*n*
- management, academic doctoral S/E's in, 48-49, 213
- non-defense, 3-5, 77, 236-237, 265
 - plant and equipment for
 - equipment spending, 14, 82-84, 256, 259-263
 - facilities spending, 14, 80-82, 256-258
 - special resources for
 - collections of research materials, 85-86
 - supercomputers, 85
 - synopsis of, 2
- Research materials, collections of, 85-86
- Restriction of research, 158-160, 338
- Retention rates in research, 92, 292
- Robotic production techniques, 67
- Russia. *See* Soviet Union.

S

- Salaries, 26, 180
- Sales workers, salaries of, 180
- SBA (Small Business Administration) classification of business, 111, 111*n*
- Scholastic Aptitude Tests (SAT's), 22-25, 175-178
- Science. *See also* Engineering; Science and engineering.
- Carnegie units required in, 32, 189
 - courses taken by precollege teachers in, 26-27, 181, 185
 - doctorates awarded in, 44-45, 202

- foreign recipients of U.S. doctoral degrees in, 92, 271-283
 - graduate S/E enrollment in, 41-44, 196-200
 - graduate students, financial support for, 45-47, 205, 206, 215
 - as an intended major of precollege students, 24-25, 177
 - NSF programs to improve teaching and learning in, 32
 - precollege
 - achievement scores in, 9-10, 21, 174
 - highlights of, 20
 - overview of, 9-10
 - and SAT scores, 22-25, 175-178
 - R&D funding in, 13-14, 79-80, 252-255
 - U.S. doctoral recipients studying abroad in, 98, 284
- Science and engineering (S/E). *See also* Engineering; Science.
- degrees in. *See* Degrees.
 - enrollments in
 - graduate, 41-44, 196-201
 - undergraduate, 10, 41, 42, 195
 - synopsis of, 2
 - workforce in
 - with bachelor's and master's degrees, 59-60, 222
 - business, 55-58, 219-221
 - demand, long-term, 67-68
 - demand, short-term, 67
 - with doctoral degrees, 60-61, 223-224
 - educational institutions, 55, 58, 219-220
 - employment rates, 64, 225
 - Federal government, 55, 58, 219-220
 - and first degrees, 5, 71, 233
 - highlights of, 52-53
 - industry, 55-58, 219-221
 - international employment, 5, 70-72, 226-229
 - labor force participation rates, 64, 225
 - minorities in, 8, 63-64, 230-232
 - other sectors, 58
 - overview of, 5-8, 66-67
 - participation rates, 64, 225
 - shortages of personnel, 65-66
 - supply, 68-70, 226
 - trends in employment, 6-7, 53-54, 216-217
 - trends in S/T activities, 54-55, 218
 - underemployment rates, 64, 225
 - underutilization rates, 65, 66, 225
 - women in, 7-8, 61-63, 70-72, 216, 220, 223-224, 226

- Science and technology (S/T)
- in industry. *See* Industrial research.
 - in the marketplace. *See* International markets for U.S. technology.
 - and public attitudes. *See* Public attitudes toward science and technology.
 - public attitudes toward policy areas in
 - advantages vs. disadvantages of various technologies, 161-162, 338-339
 - funding for basic research, 158, 159, 337
 - government regulation of S/T, 160-161
 - restriction of research, 158-160, 338
 - synopsis of, 2
 - trends in activities, 54-55, 218
 - U.S. vs. foreign, public attitudes toward, 157-159, 336-337
- Science Indicators—1985, 46
- Scientific thinking
- acceptance of, 153-156, 335
 - limits and alternatives to, 155-156, 336
- Scientists. *See also* Engineers; Scientists and engineers.

- academic doctoral employment of, 48-49, 212-214
 - defined, 52*n*
 - doctoral research S/E's, 90-91, 93-94, 269, 274
 - doctoral S/E's, 55, 56, 60-61, 220, 223, 224
 - employed S/E's, 6-8, 64-66, 216, 218, 219, 225
 - postdoctorates in doctoral-granting institutions, 43, 200
 - public attitudes toward, 152-153, 334-335
 - research S/E's, 90-91, 93-94, 268, 273
- Scientists and engineers (S/E's). *See also* Engineers; Scientists.
- assistant professors, 48, 214
 - associate professors, 48, 214
 - defined, 52*n*
 - doctoral, academic employment of, 48-49, 212-214
 - instructors, 48, 214
 - international employment of, 5, 70-72, 226-229
 - professors, 48, 214
 - workforce of. *See* Science and engineering, workforce in.
- Scotland, precollege mathematics achievement scores in, 9, 24, 33-35, 177, 192
- S/E. *See* Science and engineering.
- Second International Mathematics Study, 33, 36
- Secondary education. *See* Education, precollege.
- Secondary mathematics. *See* Mathematics, precollege.
- Secondary science. *See* Science, precollege.
- Secondary students. *See* Students, precollege.
- Secondary teachers. *See* Teachers, precollege.
- Sectoral trends
- in research
 - cross-sector co-authorships and citations, 17, 95-96, 277-279
 - cross-sector mobility, 94-95, 272, 275-276
 - retention rates, 92, 292
 - university-industry contacts, 96-98, 280-281
 - in the S/E labor force
 - business, 55-58, 219-221
 - educational institutions, 55, 58, 219-220
 - Federal government, 55, 58, 219-220
 - industry, 55-58, 219-221
 - other sectors, 58
- S/E's. *See* Scientists and engineers.
- Shortages of S/E personnel, 65-66
- SIC (Standard Industrial Classification), 109*n*, 133
- Silicon molecular-beam epitaxy, research in, 96
- Singapore, exports and imports of high-technology products, 133-135, 326
- Small Business Administration (SBA) classification of business, 111, 111*n*
- Small business in high technology, 111
- and biotechnology, 115-116, 309-311
- employment in, 111-114, 306
 - highlights of, 102
 - overview of, 16
 - venture capital and, 114-115, 306-308
- Social research data, 86
- Social sciences
- academic doctoral employment in, 48-49, 212-214
 - baccalaureate sources of doctorates in, 47-48, 207, 208, 211
 - doctoral research S/E's in, 90-91, 93-94, 269, 274

- doctoral S/E's in, 55, 56, 60-61, **220**, **223**, **224**
 doctorates awarded in, 44-45, **202**
 foreign recipients of U.S. doctoral degrees in, 92, **271**, **283**
 graduate S/E enrollment in, 41-44, **196-200**
 graduate students
 financial support for, 45-47, **205**, **206**, **215**
 time from bachelor's to doctoral degree, 45, **204**
 as an intended major of precollege students, 24-25, **177**
 postdoctorates in doctoral-granting institutions, 43, **200**
 as a probable major for freshmen, 25, 26, **179**
 R&D funding in, 13-14, 79-80, **252-254**
 research materials in, 86
 research S/E's in, 90-91, 93-94, **268**, **273**
 and SAT scores, 22-23, **175**
 S/E's employed in, 6-8, 64-66, **216**, **218**, **219**, **225**
 U.S. doctoral recipients studying abroad in, 98, **284**
 Social studies, Carnegie units required in, 32, **189**
 South Asia, foreign students in U.S. from, 44, **201**
 South Korea, exports and imports of high-technology products, 133-135, **326**
 Soviet Union
 internationally co-authored articles in, 98-99, **286**
 national R&D expenditures in, 3-4, 77, **236-237**
 public attitudes on U.S. vs. foreign S/T, 157-159, **336-337**
 S/E's employed in, 5, 71, 72, **227-228**
 U.S. academic exchange visas issued to, 98, **285**
 weaving equipment innovations in, 118-119
 Space program, public attitudes toward, 163-164
 Space sciences
 articles cross-nationally co-authored in, 17, 95-96, **285**
 articles institutionally co-authored in, 84, **264**
 articles internationally co-authored in, 98-99, **285**
 citations in articles in, 12-13, 99, **289-290**
 courses taken by precollege teachers in, 26-27, **181-183**
 U.S. and world articles in, 99, **287-288**
 Space shuttle accident, public reaction to, 141, 162-163, **343**
 Spain
 public perceptions of benefits and harms from science, 18, 147-148, **332**
 weaving equipment innovations in, 118-119
 S/T. *See* Science and technology.
 Standard Industrial Classification (SIC), 109*n*, 133
 State certification of precollege teachers, 31, **188**
 State minimum competency tests, 32, **190**
 State reforms for precollege teachers, 29-30
 State-required Carnegie units, 32, **189**
 Statistics. *See* Mathematics.
 Strong-Campbell Interest Inventory, 63
 Students
 graduate
 enrollment of, 41-44, **196-201**
 foreign, 12, 44, 45, **196**, **198**, **201**
 precollege
 attitudes toward mathematics, 36, **193-194**
 computer competence of, 21-22
 highlights of, 20
 hours of television watched by, 21
 intended majors of, 24-25, **177**
 mathematics achievement scores of, 9, 21, 24, 33-35, **174**, **177**, **192**
 mathematics courses taught to, 33-35, **191**
 overview of, 9-10
 reform movements for, 32, **189**, **190**
 SAT scores of, 22-25, **175-178**
 science achievement scores of, 9-10, 21, **174**
 undergraduate
 enrollment of, 10, 41, 42, **195**
 expected majors of freshmen, 10, 11, 25, 26, 41, 42, **179**
 foreign, 44, **201**
 highest degree planned by freshmen, 11, 41, 42
 probable career occupation of freshmen, 10, 11, 41
 Supercomputers, 85
 Supply
 of precollege teachers, 27-29, **186**
 of S/E's, 68-70, **226**
 Swaziland, precollege mathematics achievement scores in, 33-35, **192**
 Sweden
 patent citations from U.S. patents to earlier patents issued to, 110
 precollege mathematics achievement scores in, 9, 24, 33-35, **177**, **192**
 precollege mathematics courses taught in, 33-35, **191**
 public perceptions of benefits and harms from science, 18, 147-148, **332**
 U.S. patent application success rates for, 110-111, **306**
 weaving equipment innovations in, 118-119
 Switzerland
 direct investment in the U.S. by, 128-130, **318**
 patent citations from U.S. patents to earlier patents issued to, 110
 U.S. direct investment in, 125-126, 135-136, **327**
 U.S. patent application success rates for, 110-111, **307**
 weaving equipment innovations in, 118-119
 Systems engineering, doctoral S/E's in, **220**, **224**
- T**
- Taiwan
 exports and imports of high-technology products, 133-135, **326**
 U.S. academic exchange visas issued to, 98, **285**
 Teachers
 doctoral, academic employment of, 48-49, **212-214**
 precollege
 certification of, 31, **188**
 characteristics of, 25-26
 college courses taken by, 26-27, **181-185**
 demand for, 27-29, **186**
 ethnic background of, 26, **181**
 federal programs for, 31-32
 gender of, 26, **180**
 and higher education reforms, 30, 31
 in-service education of, 27, **185**
 perceptions of own qualifications, 27, 28, **185**
 private sector programs for, 31-32
 qualifications of, 27-29
 research on, 32-33
 salaries of, 26, **180**
 staff development of, 31
 and state reforms, 29-31
 and student reform movements, 32, **189**, **190**
 supply of, 27-29, **186**
 technicians employed in S/E, 56-57, **221**
 Technological innovation in industry
 efforts across U.S. industry, 16, 116-117, **312**
 highlights of, 102
 in individual technologies, 117-119
 overview of, 16
 Technology. *See also* Science and technology.
 advantages and disadvantages of, 161-162, **338-339**
 articles institutionally co-authored in, 84, **264**
 articles internationally co-authored in, 98-99, **285**
 citations in articles in, 12-13, 99, **289-290**
 international diffusion of, 123
 foreign direct investment in the U.S., 128-130, **318-319**
 highlights of, 122-123
 international direct investment, 125-128, **315-319**
 international trade in high-technology products, 15, 123-125, **313-314**, **326**
 overview of, 15
 patent licenses and technology agreements, 130-132, **320-323**
 U.S. and world articles in, 99, **287-288**
 and U.S. competitiveness, 133
 direct investment and firm competitiveness, 125-126, 135-136, **315-318**, **327**
 highlights of, 122-123
 high-technology trade competitiveness, 15, 133-135, **313-314**, **324-326**
 overview of, 15
 Television, hours watched, by precollege students, 21
 Terminology in S/T, public knowledge of, 143-144, **328-329**
 Textbook content, precollege mathematics, 35-36, **193**
 Textile technologies, innovations in, 117-119
 Thailand
 precollege mathematics achievement scores in, 33-35, **192**
 precollege mathematics courses taught in, 33-35, **191**
 Three Mile Island nuclear accident, public reaction to, 164
 Trade
 balance of, 2, 15, 124, 124*n*, 133, **313**
 international. *See* International markets for U.S. technology.
 Transition-metal silicides research in, 96
- U**
- Ulster, public perceptions of benefits and harms from science, 18, 147-148, **332**
 Underemployment in S/E, 64, **225**
 Undergraduate students. *See* Students, undergraduate.
 Underutilization in S/E, 65, 66, **225**
 Unemployment rates in S/E, 64, 65, **225**
 Uniform Federal Patent Policy Act, 108
 Union of Soviet Socialist Republics (U.S.S.R.). *See* Soviet Union.
 United Kingdom
 basic research performers in, 89, 90, **267**

direct investment in the U.S. by, 128-130, **318**
 exports of high-technology products from, 133-135, **324-326**
 industrial R&D funding and performance in, 103, **293**
 internationally co-authored articles in, 98-99, **286**
 national R&D expenditures in, 3-4, 77, **234-238**
 patent citations from U.S. patents to earlier patents issued to, 110
 precollege mathematics achievement scores in, 9, 24, 33-35, **177, 192**
 precollege mathematics courses taught in, 33-35, **191**
 public attitudes on U.S. vs. foreign S/T, 157-159, **336-337**
 public perceptions of benefits and harms from science, 18, 147-148, **332**
 royalty receipts from and payments to U.S., 130-132, **320-321**
 S/Es employed in, 5, 70-72, **226-229**
 sharing of DSDP costs by, 100
 U.S. academic exchange visas issued to, 98, **285**
 U.S. direct investment in, 125-126, 135-136, **315-317, 327**
 U.S. patent application success rates for, 110-111, **306**
 U.S. patents granted to inventors from, 107, **302**
 U.S. patents granted to inventors in, 109-110, **304-305**
 weaving equipment innovations in, 118-119
 U.S. academic exchange visas issued to foreign countries, 98, **285**

U.S. Department of Agriculture. *See* Agriculture, Department of.
 U.S. Department of Commerce. *See* Commerce, Department of.
 U.S. Department of Defense. *See* Defense, Department of.
 U.S. Department of Energy (DOE), 32
 U.S. Department of Health and Human Services. *See* Health and Human Services, Department of.
 U.S. Patent and Trademark Office, 106, 108-110
 U.S. patents. *See* Patents.
 USDA. *See* Agriculture, Department of.
 Universities. *See* Colleges and universities.
 U.S.S.R. (Union of Soviet Socialist Republics). *See* Soviet Union.

V

Venture capital, 114-115, **306-308**
 Visas, academic exchange, issued to foreign countries, 98, **285**

W

Wales. *See* United Kingdom.
 Weather satellite research data, 85
 Weaving equipment, innovations in, 118-119
 West Germany
 basic research performers in, 89, 90, **267**
 direct investment in the U.S. by, 128-130, **318**

exports of high-technology products from, 133-135, **324-326**
 industrial R&D funding and performance in, 103, **293**
 internationally co-authored articles in, 98-99, **286**
 national R&D expenditures in, 3-4, 77, **234-238**
 patent citations from U.S. patents to earlier patents issued to, 110
 public attitudes on U.S. vs. foreign S/T, 157-159, **336-337**
 public perceptions of benefits and harms from science, 18, 147-148, **332**
 royalty receipts from and payments to U.S., 130-132, **320-323**
 S/Es employed in, 5, 70-72, **226-229**
 sharing of DSDP costs by, 100
 U.S. academic exchange visas issued to, 98, **285**
 U.S. direct investment in, 125-126, 135-136, **315-317, 327**
 U.S. patent application success rates for, 110-111, **306**
 U.S. patents granted to inventors from, 107, **302**
 U.S. patents granted to inventors in, 109-110, **304-305**
 weaving equipment innovations in, 118-119
 Women. *See also* Gender comparisons
 doctoral research S/Es, 91, **270**
 S/E degrees awarded to, 45, **203**
 in the S/E workforce, 7-8, 61-63, 70-72, **216, 220, 223-224, 226**
 Work, perceived effect of S/T on, 150-152
 Workforce in S/E. *See* Science and engineering, workforce in.